RADIOCTIVITY

INTRODUCTION

Radioactivity is a process where an unstable nuclide breaks up to yield another nuclide of different composition with emission of particles and energy
Radioactive decay is the spontaneous disintegration/decay of a radioactive nuclide.
Radioisotopes are isotopes which are radioactive
.
Radioactivity is a nuclear reaction and not a chemical reaction

similarities:between Nuclear and chemical reaction

(i)-both involve the **subatomic** particles; electrons, protons and neutrons in an atom
(ii)-both involve the subatomic particles trying to make the atom more **stable**.
(iii)-Some form of **energy** transfer to the environment take place.

Differences between chemical reactions and nuclear reactions

Nuclear reaction	**Chemical reaction**
Takes place within the nucleus and involves neutrons and protons	Takes place on the outer energy elevel and only involves valency electrons
Release large amounts of heat energy	Much less energy released
Not affected by environmental factors such as temperature	Are affected by environmental factors such as temperature and pressure
New element formed	No new element formed

CHARACTERISTICS OF RADIOACTIVITY

All atoms with atomic number above 82 are radioactive
Radioactivity reactions are spontaneous and produce a lot of energy
Radioactivity is not affected by external factors like temperature and pressure
Types of radiation
There are three types of radiations emitted when radioactive nuclides disintegrate

(i)alpha(α) particle decay	(ii)Beta (β) particle decay	iii)Gamma (y) particle decay
I. Is **positive**ly charged and are attracted to the negative plate of electric field	is negatively charged hence attracted to the positive plate of electric field.	**No charge**
II. Has mass number **4** and atomic number **2** therefore equal to a charged helium atom ($^{4}_{2}he^{2+}$)	no mass number and atomic number negative one(-1) therefore equal to a fast moving electron ($^{0}_{-1}e$)	has **no** mass number and atomic number therefore equal to **electromagnetic waves**.
they show a lesser deflection by electric filed ,due to their large mass	**Show are greater deflection due to the lesser mass**	**Not deflected**
have very **low** penetrating power and thus can be stopped a thin sheet of	Have medium penetrating power and thus can be stopped thin sheet of aluminum foil.	very **high** penetrating power and thus can be stopped by a thick block of lead..
I. have **high** ionizing power thus cause a lot of **damage** to living cells.	Have medium ionizing power thus cause less damage to living cells than α particle.	have very **low** ionizing power thus cause less damage to living cells unless on prolonged exposure

Alpha decay;

a nuclide undergoing α-decay has its mass number **reduced** by **4** and its atomic number **reduced** by **2**

Examples of alpha decay

$^{210}_{84}Pb \longrightarrow ^{206}_{82}Pb + ^{4}_{2}He^{2+}$

$^{226}_{88}Ra \longrightarrow ^{222}_{88}Rn + ^{4}_{2}He^{2+}$

complete the equations below

$^{266}_{106}Sg \longrightarrow ^{m}_{n}RF + ^{4}_{2}He^{2+}$

$^{251}_{98}Cf \longrightarrow ^{238}_{92}U +$ ……………………

$^{285}_{112}Cn \longrightarrow ^{p}_{q}Hs + 2\ ^{4}_{2}He^{2+}$

$^{z}_{a}Es \longrightarrow ^{235}_{93}Np + 3\ ^{4}_{2}He^{2+}$

$^{288}_{114}Uuq \longrightarrow ^{278}_{104}Rf$ + ...

$^{226}_{88}Ra \longrightarrow ^{218}_{84}Rn$ +

<u>beta (β) decay</u>

v) a nuclide undergoing β -decay has its mass number **remain** the same and its atomic number **increase** by **1**

<u>Examples of beta (β) decay</u>

$^{228}_{88}Ra \longrightarrow ^{228}_{89}Ac + ^{0}_{-1}e$

$\mathbf{^{228}_{88}Ra \longrightarrow ^{228}_{92}Th}$ **+**

. $^{232}_{90}Th \longrightarrow ^{232}_{91}Pb$ +

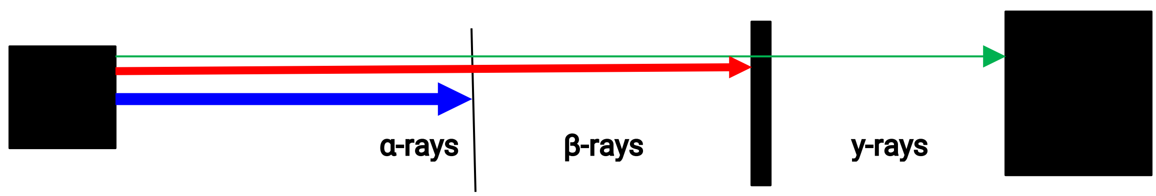
$\mathbf{^{I}_{k}Th \longrightarrow ^{212}_{93}Np}$ **+ 3** $^{0}_{-1}e$

Gamma y -decay

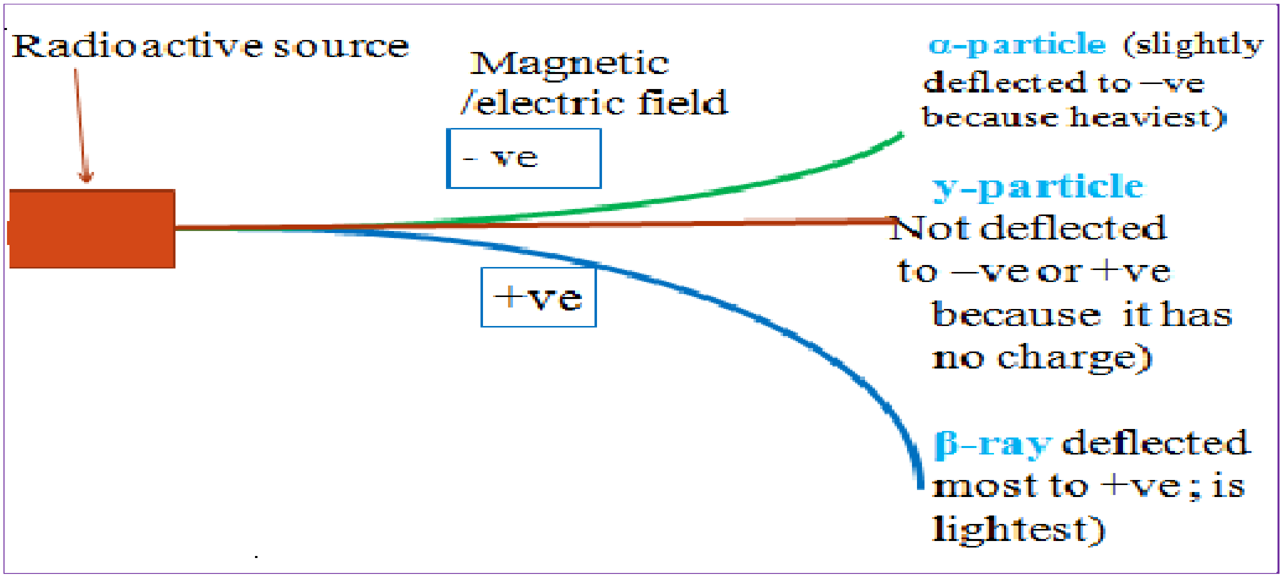
v) a nuclide undergoing y -decay has its mass number and its atomic number **remain** the **same**.

The sketch diagram below shows the **penetrating power** of the radiations from a radioactive nuclide.

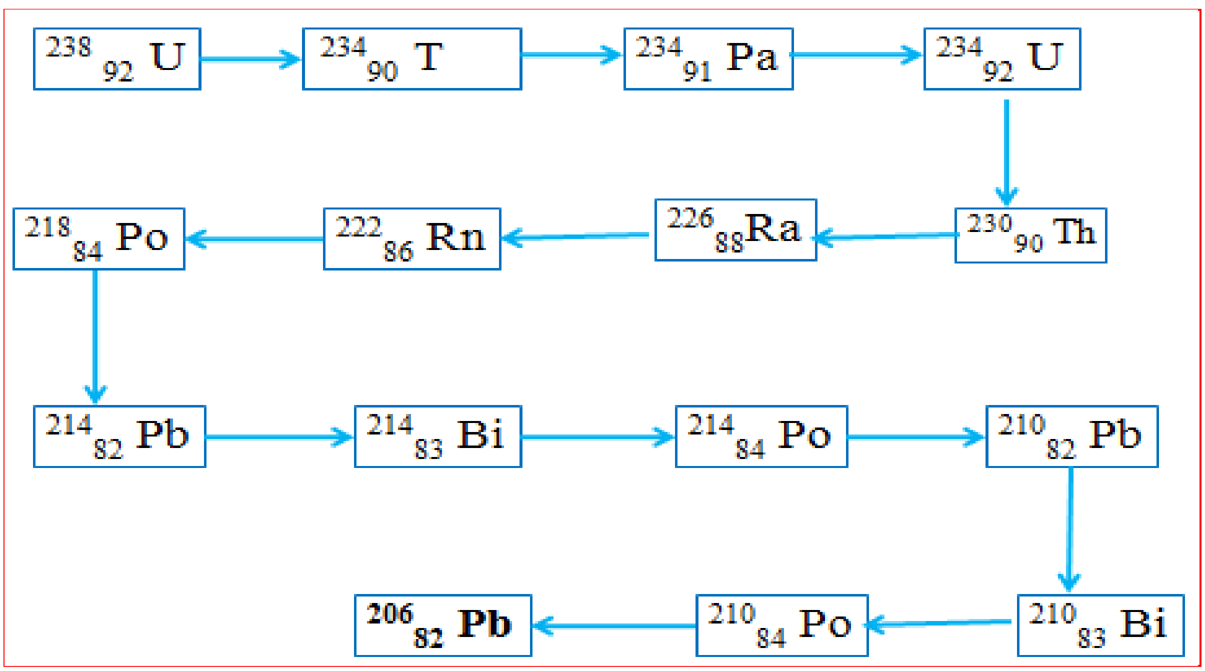
radioactive nuclide (radiation source) **sheet of paper (block α-rays)** **aluminium foil (block β-rays)** **thick block of lead block y-rays)**



The sketch diagram below illustrates the effect of **electric** /**magnetic field** on the three radiations from a radioactive nuclide



Radioactive disintegration/decay **naturally** produces the stable $^{206}_{82}Pb$ nuclide /isotope of lead.Below is the $^{238}_{92}U$ natural decay series. Identify the particle emitted in each case



B:NUCLEAR FISSION AND NUCLEAR FUSION

Radioactive disintegration/decay can be initiated in an industrial laboratory through two chemical methods:

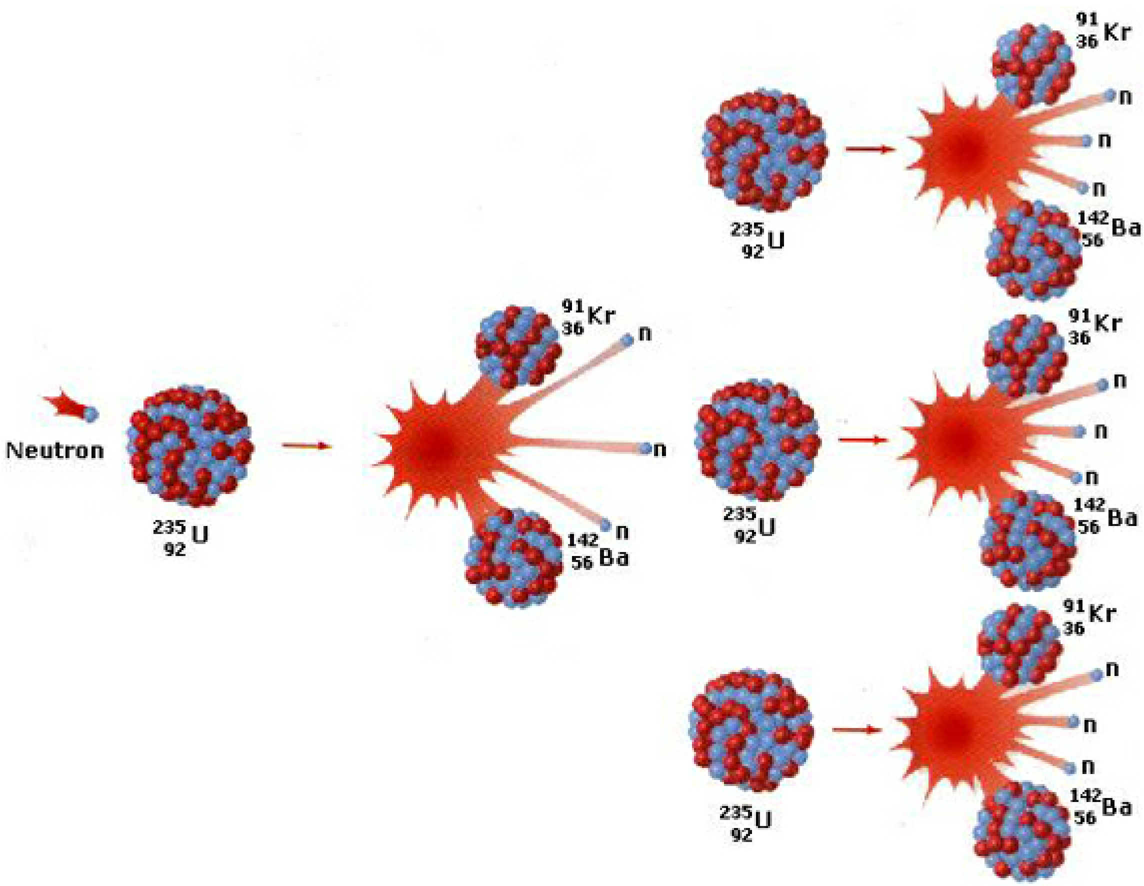
a) nuclear **fission**

b) nuclear **fusion.**

a)Nuclear fission

Nuclear fission is the splitting process of a a heavy **unstable** nuclide releasing **lighter** nuclides,

and a large quantity of **energy** when bombarded /hit by a fast moving neutron
Nuclear fission is the basic chemistry behind **nuclear bombs** made in the nuclear reactors.



Examples of nuclear equations showing nuclear fission

Supply the missing information to te equations below

$^{1}_{0}n + ^{235}_{b}U \longrightarrow ^{90}_{38}Sr + ^{a}_{54}Xe + 3\,^{1}_{0}n$ + energy

$^{1}_{0}n + ^{27}_{13}Al \longrightarrow ^{28}_{13}Al + y$ + energy

$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{147}_{57}La + ^{87}_{35}Br$ + ---- + energy

$^{1}_{0}n + ^{235}_{b}U \longrightarrow ^{1}_{0}n$ + ………….. energy

$^{247}_{96}Cm + ^{1}_{0}n \longrightarrow$ ……….+ $^{1}_{0}n$ + energy

$^{235}_{95}U + ^{1}_{0}n \longrightarrow .... + ^{142}_{56}Ba + 3^{1}_{0}n + \text{energy}$

NUCLEAR FUSION.

Nuclear fusion is the process which **smaller** nuclides join together to form **larger** / heavier nuclides releasing a large quantity of **energy**..

Nuclear fusion is the basic chemistry behind solar/sun radiation.

Two daughter atoms/nuclides of Hydrogen fuse/join to form Helium nuclide on the surface of the sun releasing large quantity of energy in form of heat and light

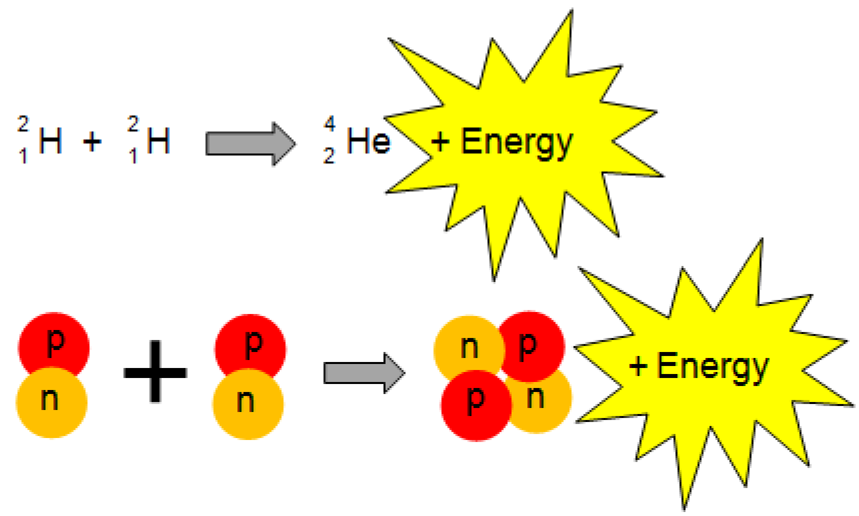
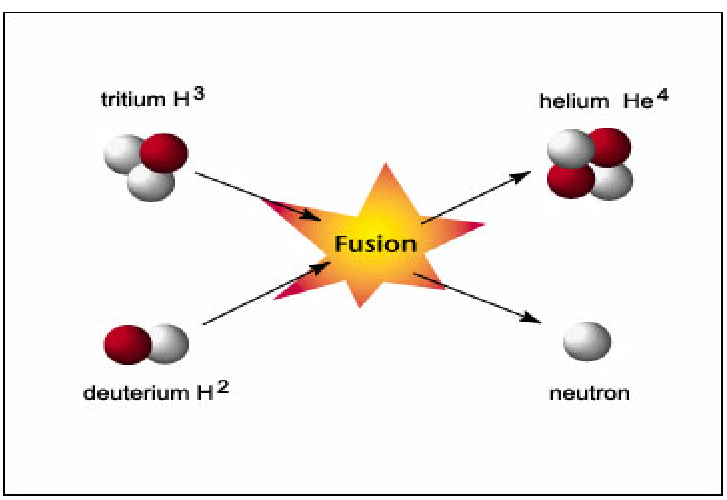


Figure 1



$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{a}_{b}He + ^{1}_{0}n + \text{energy}$

$^{2}_{1}H$ + $^{2}_{1}H$ → ……….. + $^{1}_{1}H$+ energy

$^{14}_{7}N$ + ………… → $^{17}_{8}O$ + $^{1}_{1}H$+ energy

$^{53}_{24}N$ + $^{4}_{2}He$ → $^{1}_{0}n$ + …………….+ energy

Similarities between nuclear fusion and nuclear fission

In both a large quantity of energy
Both processes results in chain reactions
In both cases sub-atomic particles such as neutrons accompany the peocess

Differences between nuclear fusion and nuclear fission

Nuclear nuclear fission	**nuclear fusion**
Heavy nucleus is split to smaller nuclei	Smaller nuclei combine to form heavy nucleus
Have a lower activation energy	Have a higher activation energy
Produces larger amount of energy than nuclear fusion	Produces relatively lower amount of energy

: HALF LIFE PERIOD ($t^1/_2$)

The half-life period is the **time** taken for a radioactive nuclide to spontaneously decay/ disintegrate to **half** its **original** mass/ amount.
It is usually denoted **$t\ ^1/_2$**.
The rate of radioactive nuclide disintegration/decay is **constant** for each nuclide.

The table below shows the half-life period of some elements.

Element/Nuclide	Half-life period($t\ ^1/_2$)
$^{238}_{92}U$	4.5×10^{9} years
$^{14}_{6}C$	5600 years
$^{229}_{88}Ra$	1620 years

The **less** the half life the **more unstable** the nuclide /element.
The half-life period is determined by using a Geiger-Muller counter (**GM tube**)
.A GM tube is connected to ratemeter that records the **count-rates per unit time**.
This is the rate of decay/ disintegration of the nuclide.
If the count-rates per unit time **fall** by **half**, then the **time** taken for this **fall** is the half-life period.

APPLICATIONS OF HALF LIFE

I. Carbon dating
II. Detecting leakages
III. Monitoring plant growth
IV. In medicine to monitor plant growth.

Examples

a)A radioactive substance gave a count of 240 counts per minute but after 6 hours the count rate were 30 counts per minute. Calculate the half-life period of the substance.

If $t^{1}/_{2} = x$

then 240 → 120 → 60 → 30

From 240 to 30 =3x =6 hours

=>x = $t^{1}/_{2}$ = (6 / 3)

= **2 hours**

b) The count rate of a nuclide fell from 200 counts per second to 12.5 counts per second in 120 minutes.
Calculate the half-life period of the nuclide.

c) After 6 hours the count rate of a nuclide fell from 240 counts per second to 15 counts per second on the GM tube. Calculate the half-life period of the nuclide.

d) Calculate the mass of nitrogen-13 that remain from 2 grams after 6 half-lifes if the half-life period of nitrogen-13 is 10 minutes.

e) What fraction of a gas remains after 1hour if its half-life period is 20 minutes?

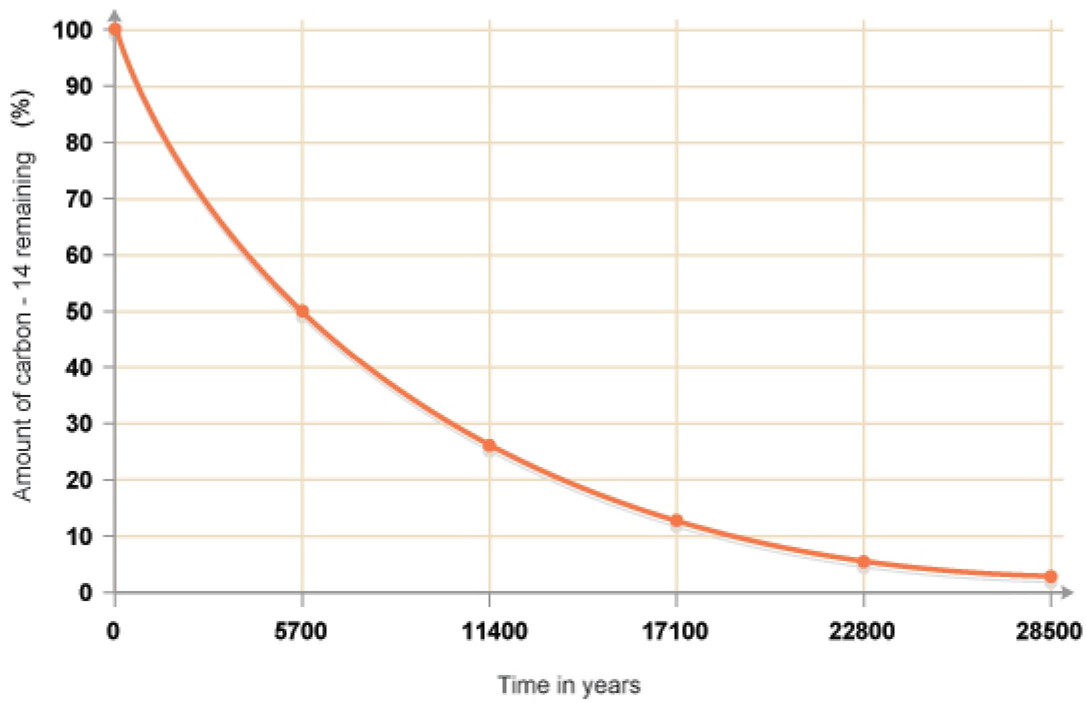
f) 348 grams of a nuclide A was reduced to 43.5 grams after 270days.Determine the half-life period of the nuclide.

g) How old is an Egyptian Pharaoh in a tomb with 2grams of ^{14}C if the normal ^{14}C in a present tomb is 16grams.The half-life period of ^{14}C is 5600years.

h) 100 grams of a radioactive isotope was reduced 12.5 grams after 81days.Determine the half-life period of the isotope.

A graph of activity against time is called **decay curve.**
A decay curve can be used to determine the half-life period of an isotope since activity decrease at equal time interval to half the original

The graph below shows the rate of decay of carbon-14



(i)From the graph show and determine the half-life period of the isotope.

From the graph $t\ ^1/_2$ changes in activity from:

(100 – 50) => (5700 – 0) = **5700 years**

(50 – 25) => (11400 – 5700) = **5700 years**

Thus $t^{½}$ = **<u>5700 years</u>**

(ii)Why does the graph tend to 'O'?

Smaller particle/s will disintegrate /decay to half its original.

There can <u>never</u> be 'O'/zero particles

The table below shows the change in mass of a radioactive isotope with time

Time (days)	0	2	4	6	8	10	12	14	16	18
Mass (g)	10.0	8.7	7.5	6.2	5.0	4.1	3.4	2.9	2.5	2.3

On the grid provided ,plot a graph of the percentage of bismuth remaining against time. (3mks)

a) From the graph determine

I. half life of the radioisotope

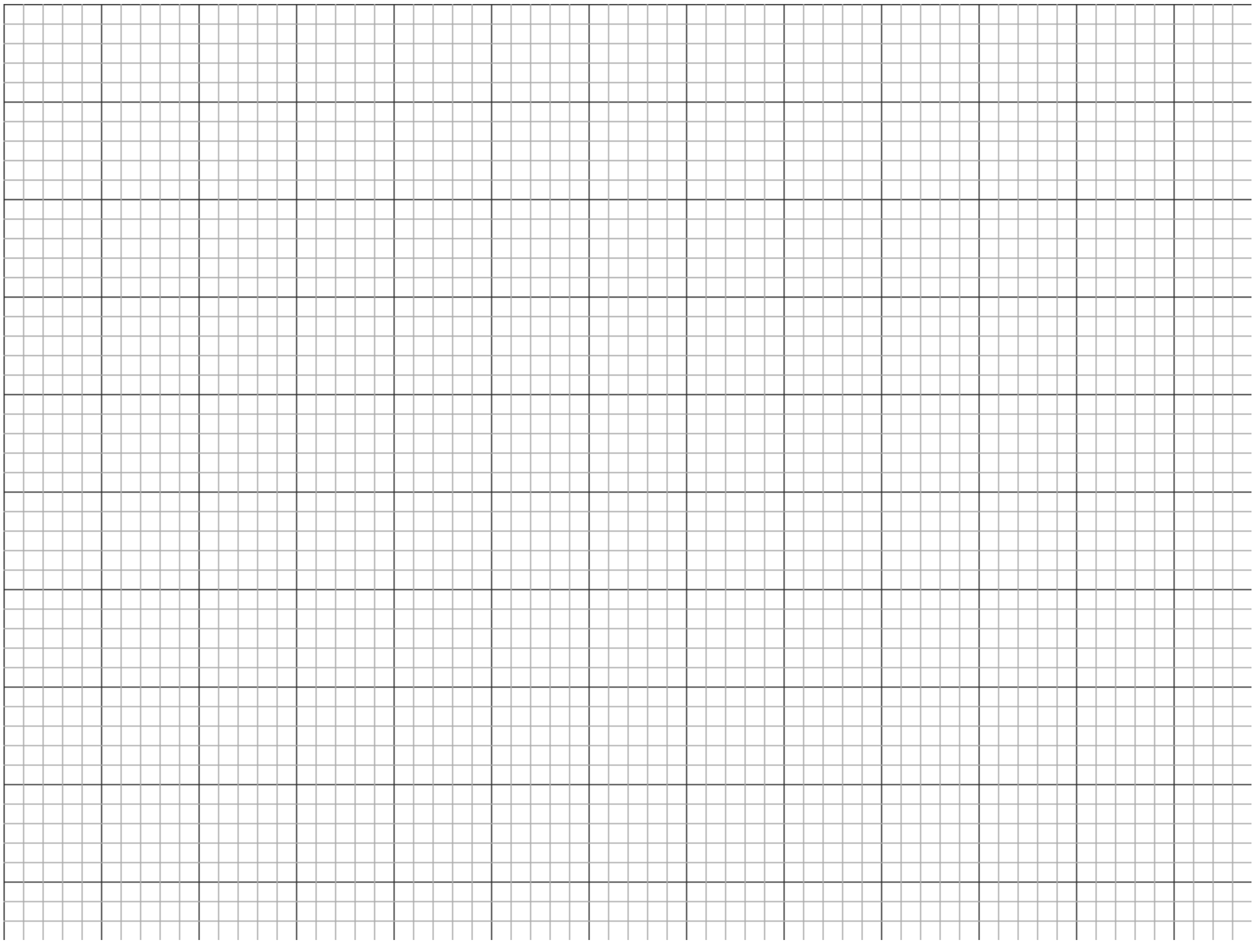
II. the mass after the 7th day

III. the mass after the 20th day

IV. The table below shows the measurements of radioactivity in counts per minute from a radioisotope iodine-128

Counts per minute	240	204	176	156	138	122	112
Time in days	0	5	10	15	20	25	30

a) Plot a graph of counts per minute against time



b) Use your gaph to determine the half life of iodine-128

b) From youethe graph determinecount rate after;

I. 12 minutes

II. 22minutes

c) After how many minutes was the count rate ;

(i) 160 counts per minute

(ii) 197 counts per minute

A quantity of ^{44}Y was monitored with a GM tube and the folllowinf results were obtained over a period of 70 minutes.

Counts per minute	800	580	427	305	225	165	122	85
Time	0	10	20	30	40	50	60	70

I. the grid provided plot a graph of counts per minute against time.

II. Determne the half life of Y

III. On Starting with 32g of ^{44}Y,how much of the isotope would remain after 110 minutes.

IV. Give two applications of half life

<u>E: APPLICATION AND USES OF RADIOCTIVITY.</u>

The following are some of the fields that apply and use radioisotopes;

a)**Medicine: -**

- Treatment of cancer to **kill** malignant tumors through **radiotherapy e,g colbalt-60 and caesium-137**
- -**Sterilizing** hospital /surgical instruments by exposing them to gamma radiation.
- -to monitor growth in bones and healing of fractures
- For providing power in heart pacesetters

b) Agriculture:

- monitor plant growth by tracing the route of the radioisotope.
- Radioactive phosphorus is used to determine rate of absorption of phosphate fertilizers

c) Food preservation:

X-rays are used to kill bacteria in **tinned** food to last for a long time.

d) Chemistry:

To study **mechanisms** of a chemical reaction, one reactant is **replaced** in its structure by a radioisotope e.g.

During esterification the **'O'** joining the ester was discovered comes from the **alkanol** and not alkanoic acid.

During photosynthesis the **'O'** released was discovered comes from **water**.

e) Dating rocks/fossils:

Comparing the mass of ^{14}C in **living** and **dead** cells, to determine their age,

<u>F: DANGERS OF RADIOCTIVITY.</u>

1. Exposure to theses radiations causes **chromosomal** and /or **genetic** mutation in living cells.
2. Living things should therefore **<u>not</u>** be exposed for a long time to radioactive substances.
3. One of the main uses of radioactive isotopes is in generation of large cheap **electricity** in <u>nuclear reactors</u>.
4. Those who work in these reactors must wear <u>protective</u> devises made of **thick** glass or **lead** sheet.
5. Accidental <u>leakages</u> of radiations usually occur
6. In 1986 the Nuclear reactor at **Chernobyl** in Russia had a major <u>explosion</u> that emitted poisonous nuclear material that caused immediate <u>environmental</u> disaster
7. In 2011, an **earthquake** in Japan caused a nuclear reactor to leak and release poisonous radioactive waste into the Indian Ocean.
8. The immediate and long term effects of exposure to these **poisonous** radioactive waste

on human being is of major concern to all <u>environmentalists</u>.

Control
Proper use,storage and disposal of radioactive materials
Regular checks of equipment which emit radiations

Revision quiz RADIOACTIVITY

1. 1993 Q P1A 7
The Table below gives the rate of decay for radioactive element Y.

Number of days	Mass (g)
0	384
270	48

Calculate the half-life of the radioactive element Y.

2. 1995 P1A Q30
(a) 100g of radioactive $^{233}_{91}Pa$ was reduced to 12.5g after 81 days.
Determine the half-life of Pa. (2 marks).

b) 23391 Pa decays by Beta emission. What is the mass number and the atomic number of the element formed? (1 mark)

3. 1996 P1A Q 20
Complete the diagram below to show how α and β particles from radioactive can be distinguished from each other. Label your diagram clearly. (3 marks)

4. 1997 P1A Q 7
M grammes of a radioactive isotope decayed to 5 grammes in 100 days.
The half –life of the isotope is 25 days.
(a) What is meant by half-life? (1 mark)

……
……………………………………………………………………………………

(b) Calculate the initial mass M of the radioactive isotope. (2 marks)

....
....
....

5. 1998 P1A Q1

An isotope of Uranium $^{234}_{94}U$ decays by emission of an alpha particle to thorium. Th.

(a). Write the equation for the nuclear reaction undergone by the isotope. (1 mark)

....

(b). Explain why it is not safe to store radioactive substances in containers made from Aluminum sheets. (1 mark)

....
....
....

6. 2000 Q 13

A radioactive isotope X_2 decays by emitting two alpha (a) particles and one beta (β) to from $^{214}_{83}Bi$

(a) What is the atomic number of X_2?

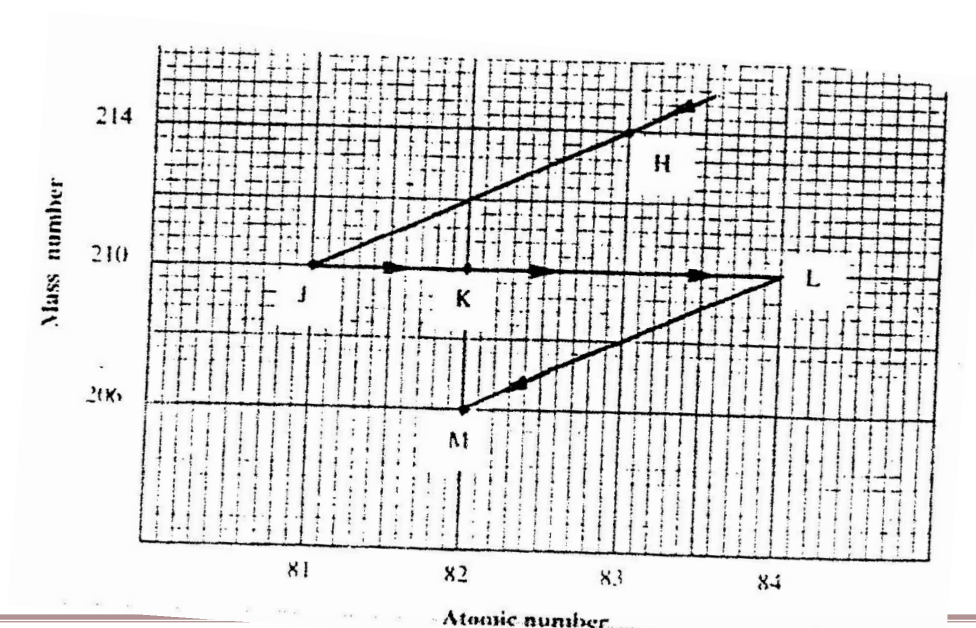
....
....
....

(b) After 112 days, $^{1}/_{16}$ of the mass of X_2 remained. Determine the half life of X_2

....
....
....

7. 2002 Q 10

The graph below represents a radioactive decay series for isotope H. Study it and answer the questions that follow



(a) Name the type of radiation emitted when isotope H changes to isotope J.

....

(b) Write an equation for the nuclear reaction that occur when isotope J changes to isotope K

....

c) Identify a pair of isotope of an element in the decay series

....
....

8. 100 g of a radioactive substance was reduced to 12.5 g in 15.6 years. Calculate the half – life of the substance. (2 marks)

....
....
....

9. (a) Complete the nuclear equation below. (1 mark)

$$^{37}_{18}A \longrightarrow \, ^{37}_{19}B + \ldots\ldots\ldots\ldots$$

....
....

(b) State one:

(i) Use of radioisotopes in agriculture (1mark)

....

(ii) Danger associated with exposure of human beings to radioisotopes (1 mark)

....

10. 2007 Q 14

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

....
....
....
....

Describe how solid wastes containing radioactive substances should be disposed of. (1 mark)

....

....
....
....

11,. 2008 Q 24

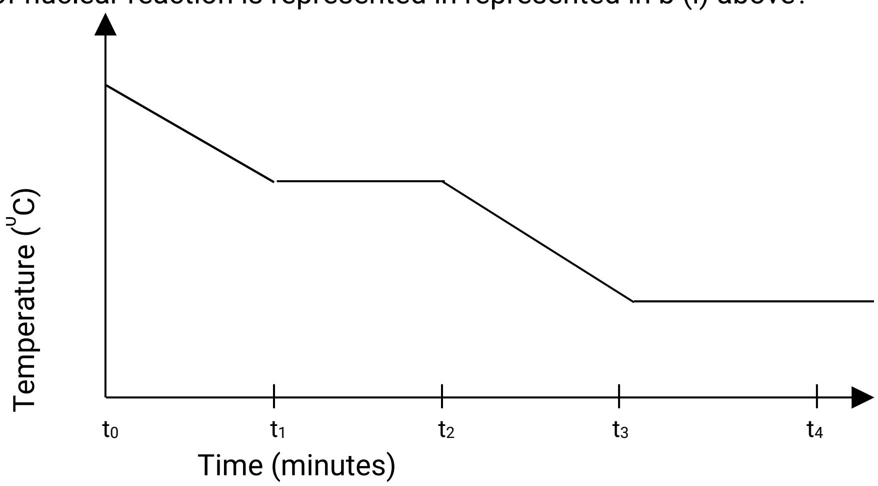
a) A radioactive substance emits three different particles. Give the symbol of the particle with the highest mass. (1 mark)

....

b) (i) Find the values of Z_1 and Z_2 in the nuclear equation below

$$^{Z1}_{92}U + {}^{1}_{0}n \rightarrow {}^{94}_{38}Sr + {}^{140}_{Z0}X_e + 2\,{}^{1}_{0}n$$

ii) What type of nuclear reaction is represented in represented in b (i) above? (1mark)



Give the name of the:

a) Process taking place between t_0 and t_1. (1mark)

....

b) Energy change that occurs between t_3 and t_4

....

12. 2009 Q 6d P2

(d) Naturally occurring uranium consist of three isotopes which are radioactive.

Isotopes	234 u	235u	238u
Abundance	0.01%	0.72%	99.27%

(i) Which of these isotopes has the longest half-life? Give reasons. (1 mark)

....
....

(ii) Calculate the relative atomic mass of uranium. (2 marks)

....
....
....

....
(iii) $^{235}_{92}U$ is an alpha emitter .If the product of the decay of this nuclide is thorium (Th) .Write a nuclear equation for the process. (1 mark)

....

iv) State one use of radioactive isotopes in the paper industry (2 marks)

....
....

13. 2011 Q 2

Complete the nuclear equation below:

$^{131}_{53}I \rightarrow ^{131}_{54}Xe +$ ________

The half life of $^{131}_{53}I$ is 8 days.

Determine the mass of $^{131}_{53}I$ remaining if 50 grammes decayed for 40 days.

....
....
....

Give one harmful effect of radioisotopes. (1 mark)

....

14. 2012 Q9 P1

120g of iodine – 131 has a half life of 8 days decays for 32 days. On the grid provided, plot a graph of the mass of iodine – 131 against time. (3 marks)