Detection of Radioactivity
Characteristics of the Three Types of Emission
Nuclear Reactions
Half-Life
Uses of Radioactive Isotopes Including Safety Precautions

RADIOACTIVITY

Detection of radioactivity

Describe the detection of alpha-particles, beta-particles and gamma-rays by appropriate methods.

Radioactivity

- Radioactivity is the process whereby unstable atomic nuclei release energetic subatomic particles.
- Radioactivity was first discovered in 1896 by the French scientist Henri Becquerel, after which the SI unit for radiation, the Becquerel, is named.

Rock resting on covered film.

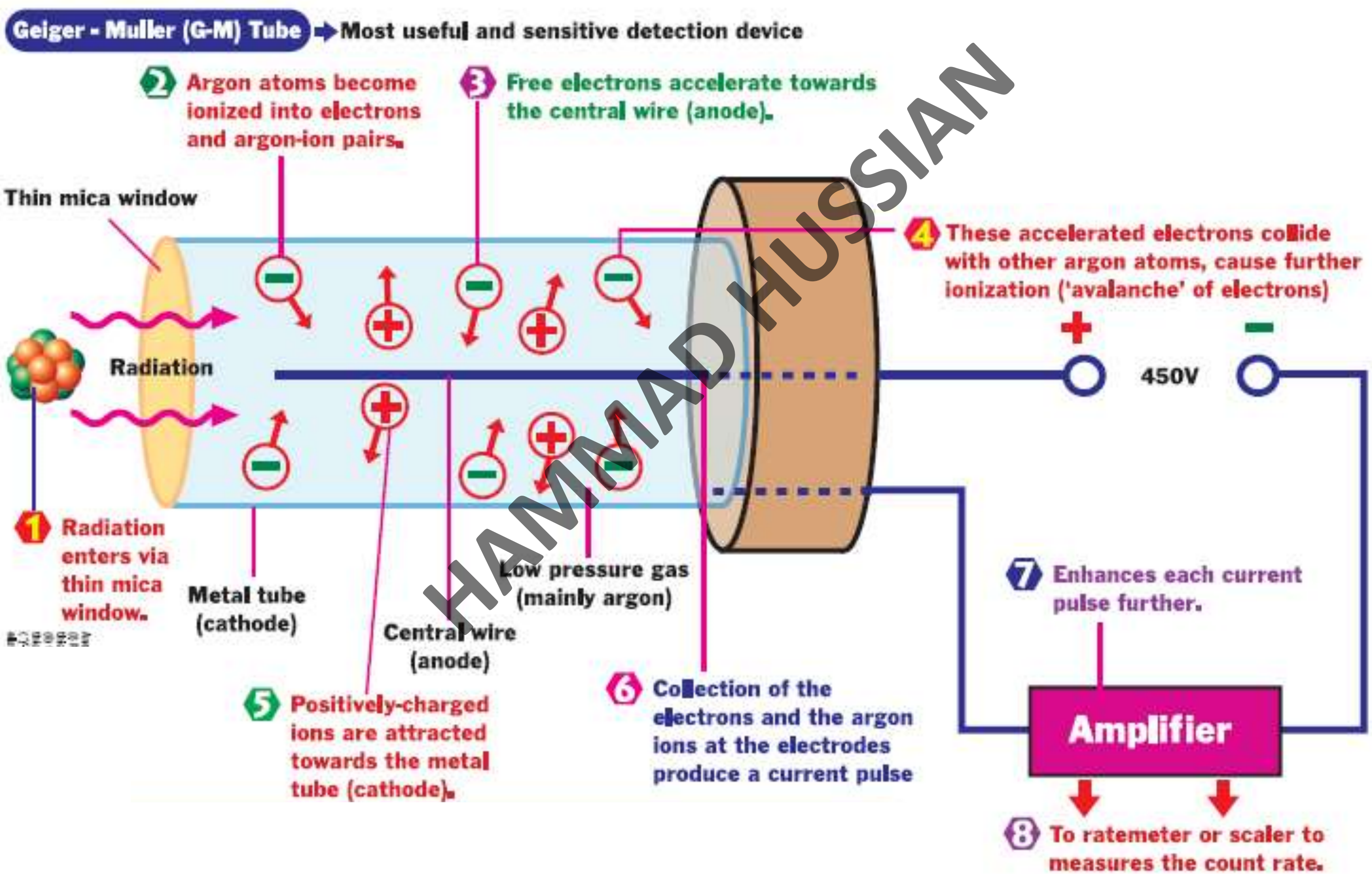
Shadow on developed film.

Detection of Radioactivity

- Radiation can not be detected with our five senses, special detectors are therefore needed.
- Several devices have been developed to detect radioactivity, with the earliest being an unexposed photographic plate placed in the vicinity of a source being detected.
- Other devices include:
  - the cloud chamber,
  - electroscopes,
  - the Geiger-Müller tube

Geiger-Müller tube

- It was named for Hans Geiger who invented the device in 1908 and Walther Müller who collaborated with Geiger in developing further in 1928



Geiger - Muller (G-M) Tube
Most useful and sensitive detection device
2 Argon atoms become ionized into electrons and argon-ion pairs.
3 Free electrons accelerate towards the central wire (anode).
Thin mica window
4 These accelerated electrons collide with other argon atoms, cause further ionization ('avalanche' of electrons)
Radiation
450V
1 Radiation enters via thin mica window.
Metal tube (cathode)
Low pressure gas (mainly argon)
Central wire (anode)
7 Enhances each current pulse further.
5 Positively-charged ions are attracted towards the metal tube (cathode).
6 Collection of the electrons and the argon ions at the electrodes produce a current pulse
Amplifier
8 To ratemeter or scaler to measures the count rate.

Characteristics of the three types of emission

State and explain the random emission of radioactivity in direction and time.

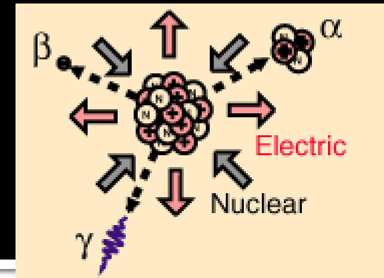
Nuclear Radiation

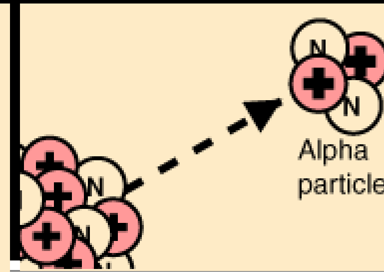
- Most nuclei are stable, but some are unstable which will emit a tiny particle called nuclear radiation.
- The emission occurs spontaneously and randomly over space and time.

Characteristics of the three types of emission

State, for radioactive emissions, their nature, relative ionising effects and relative penetrating powers.

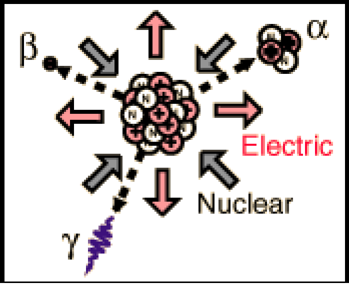
Alpha Particle

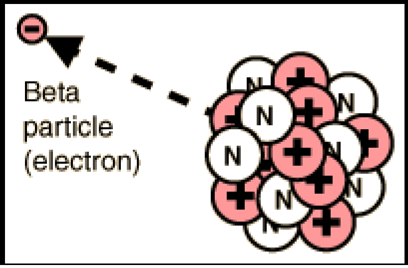




- Alpha particles are a highly ionising form of particle radiation. In cloud chamber they produce thick straight tracks.
- They consist of two protons and two neutrons bound together into a particle identical to a helium nucleus; hence, it can be written as He^{2+}.
- As its ionising power is so high it does not penetrate very deeply into matter before its energy has been used up. Its penetrating power is therefore very low (absorbed by 10 cm of air, 0.01 mm lead or a sheet of paper).

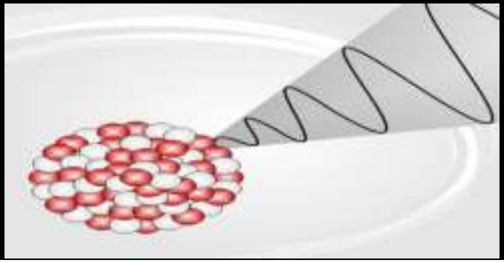
Beta Particle





- Beta particles are high-energy, high-speed electrons emitted by certain types of radioactive nuclei such as potassium-40.
- The beta particles emitted are a form of ionising radiation also known as beta rays.
- The high energy electrons have greater range of penetration than alpha particles, but still much less than gamma rays.

Gamma Ray

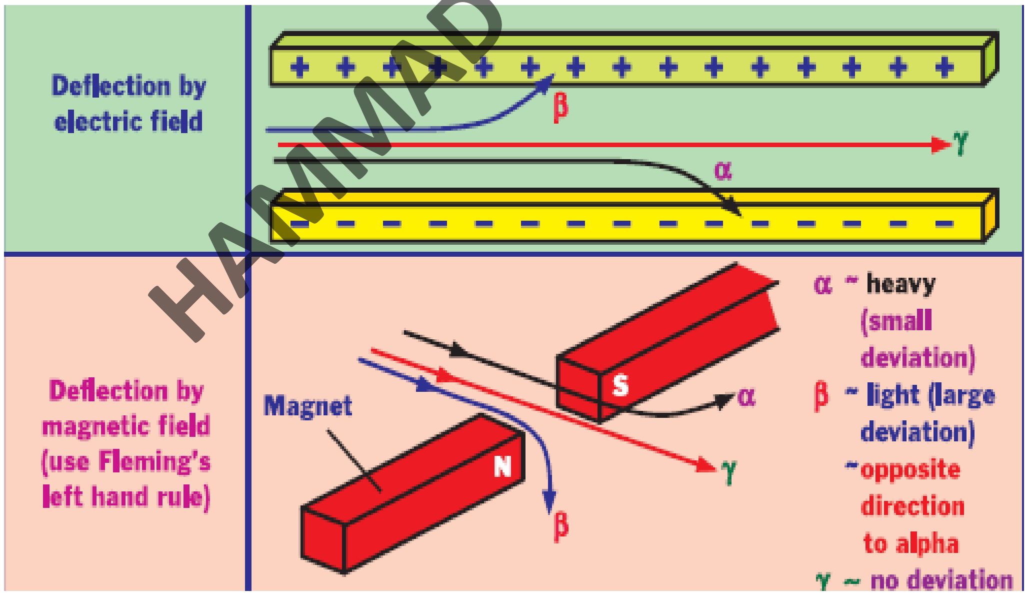


- Gamma rays are forms of electromagnetic radiation (EMR) or light emissions of a specific frequency produced from sub-atomic particle interaction and radioactive decay.
- Gamma rays are generally characterized as EMR, having the highest frequency and energy, and also the shortest wavelength, within the electromagnetic radiation spectrum.
- Its ionising power is so low it penetrates very deeply into matter before its energy has been used up.

Characteristics of the three types of emission

Describe the deflection of radioactive emissions in electric fields and magnetic fields.

- The products of radioactivity could be analyzed into three distinct species by either a magnetic field or an electric field.



type of radiation	alpha particles (α)	beta particle (β)	gamma rays (γ)
	each particle is 2 protons + 2 neutrons (it is identical to a nucleus of helium-4)	each particle is an electron (created when the nucleus decays)	electromagnetic waves similar to X-rays
relative charge compared with charge on proton	+2	–1	0
ionising effect	strong	weak	very weak
penetrating effect	not very penetrating: stopped by a thick sheet of paper, by skin or by a few centimetres of air	penetrating, but stopped by a few millimetres of aluminium or other metal	very penetrating, never completely stopped, though lead and thick concrete will reduce intensity
effect of field	deflected by magnetic and electric field	deflected by magnetic and electric field	not deflected by magnetic or electric fields

Nuclear reactions

Explain what is meant by radioactive decay.

Radioactive Decay

- It is process of spontaneous transformation of a radionuclide by the emission of nuclear radiation.
- The emission of the nuclear radiation is a purely random event. It cannot be predicted exactly when an atom will decay, only that a certain number will decay in a given time.
- The rate of decay depends on the number of undecayed nuclei present, so with each decay event there is a decrease in the activity of a radioactive sample.

NUCLEAR REACTIONS

Use the nuclide notation ${}^{A}_{Z}X$ to construct equations where radioactive decay leads to changes in the composition of the nucleus.

Nuclear Equation

- Nuclear equations can be used to show the decay process.
- These must balance for nucleon number and proton number.
- Alpha decay
  - When alpha decay occurs a group of two protons and two neutrons (helium nucleus) comes out of the nucleus. Therefore the proton number decreases by 2 but the nucleon number decreases by 4. The resulting daughter nucleus is of an element 2 positions to the left of the 'parent' in the periodic table.

$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$$

  - Look at the numbers on the top line (the nucleon numbers).
    - 238 = 234 + 4. Therefore the nucleon numbers balance
  - Look at the numbers on the bottom line (the proton numbers).
    - 92 = 90 + 2. Therefore the proton numbers balance

- Beta decay
  - When beta decay occurs a neutron within the nucleus emits the particle and changes into a proton. Therefore the proton number increases by one but the nucleon number stays the same. The resulting daughter nucleus is of an element 1 position to the right.

$$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}\beta$$

  - Look at the numbers on the top line (the nucleon numbers).
    - 14 = 14 + 0 Therefore the nucleon numbers balance
  - Look at the numbers on the bottom line (the proton numbers).
    - 6 = 7 + (-1) Therefore the proton numbers balance

- Gamma Emission
  - Sometimes, after its emission of an alpha, beta or positron particle, the nucleus is still in an excited state, called a metastable state.
  - In order to get to a lower energy state it emits a quantum of energy in the form of a gamma ray.

Problem Solving 1

Fill in the gaps in the following radioactive decay equations;

1. $^{3}H \rightarrow {}_{2}He + {}^{0}e$
2. $^{229}Th \rightarrow Ra + {}^{4}_{2}He$
3. $^{14}_{6}C \rightarrow ? + {}^{0}_{-1}e$
4. $^{209}_{82}Pb \rightarrow {}_{83}Bi + ?$
5. $^{225}_{89}Ac \rightarrow {}_{87}Fr + ?$
6. $^{28}Al \rightarrow ? + \beta$
7. $? \rightarrow {}^{234}Th + \alpha$
8. $^{210}Bi \rightarrow ? + \alpha$
9. $^{35}S \rightarrow ? + \beta$

Problem Solving 2

1. Write a nuclear equation for the alpha decay of $^{231}_{91}Pa$.
2. Write a nuclear equation for the beta decay of $^{223}_{87}Fr$.
3. Write a nuclear equation for the alpha decay of $^{149}_{62}Sm$.
4. Write a nuclear equation for the beta decay of $^{165}_{61}Pm$.
5. Write a nuclear equation for the alpha decay of $^{249}_{101}Md$.
6. Write a nuclear equation for the alpha decay of $^{146}_{62}Sm$.
7. Write a nuclear equation for the beta decay of $^{198}_{85}At$.
8. Write a nuclear equation for the alpha decay of $^{150}_{64}Gd$.
9. Write a nuclear equation for the beta decay of $^{152}_{54}Xe$.
10. Write a nuclear equation for the beta decay of $^{120}_{55}Cs$.

Nuclear reactions

Explain the processes of fusion and fission.

Nuclear Reaction

- Nuclear fusion is the process by which multiple atomic nuclei join together to form a heavier nucleus. It is accompanied by the release or absorption of energy.
- Nuclear fission is a process in nuclear physics in which the nucleus of an atom splits into two or more smaller nuclei as fission products, and usually some by-product particles.

Nuclear reactions

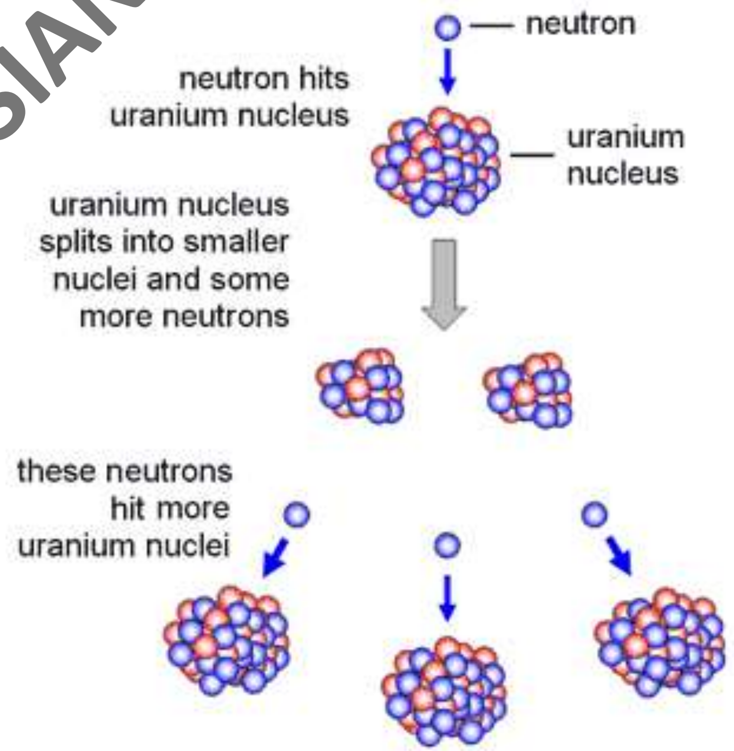
Describe, with the aid of a block diagram, one type of fission reactor for use in a power station.

Nuclear Reactor

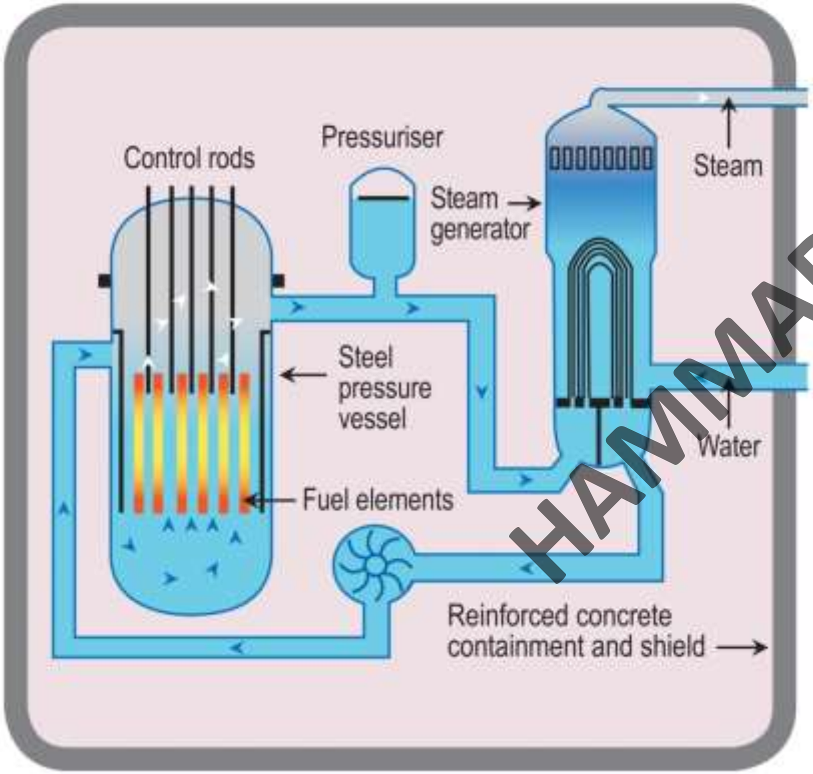
- A nuclear reactor produces and controls the release of energy from splitting the atoms of uranium.
- Uranium-fuelled nuclear power is a clean and efficient way of boiling water to make steam which drives turbine generators.

Chain Reaction

- In the reactor core the uranium-235 isotope fissions or splits, producing a lot of heat in a continuous process called a chain reaction.
- The process depends on the presence of a moderator such as water or graphite, and is fully controlled.



Energy Transformation



- Fuel produces heat, which is used to boil water to make steam.
- Steam spins a turbine.
- Turbine drives a generator and the generator makes electricity.
- Electricity goes to the transformers to produce the correct voltage.

Nuclear reactions

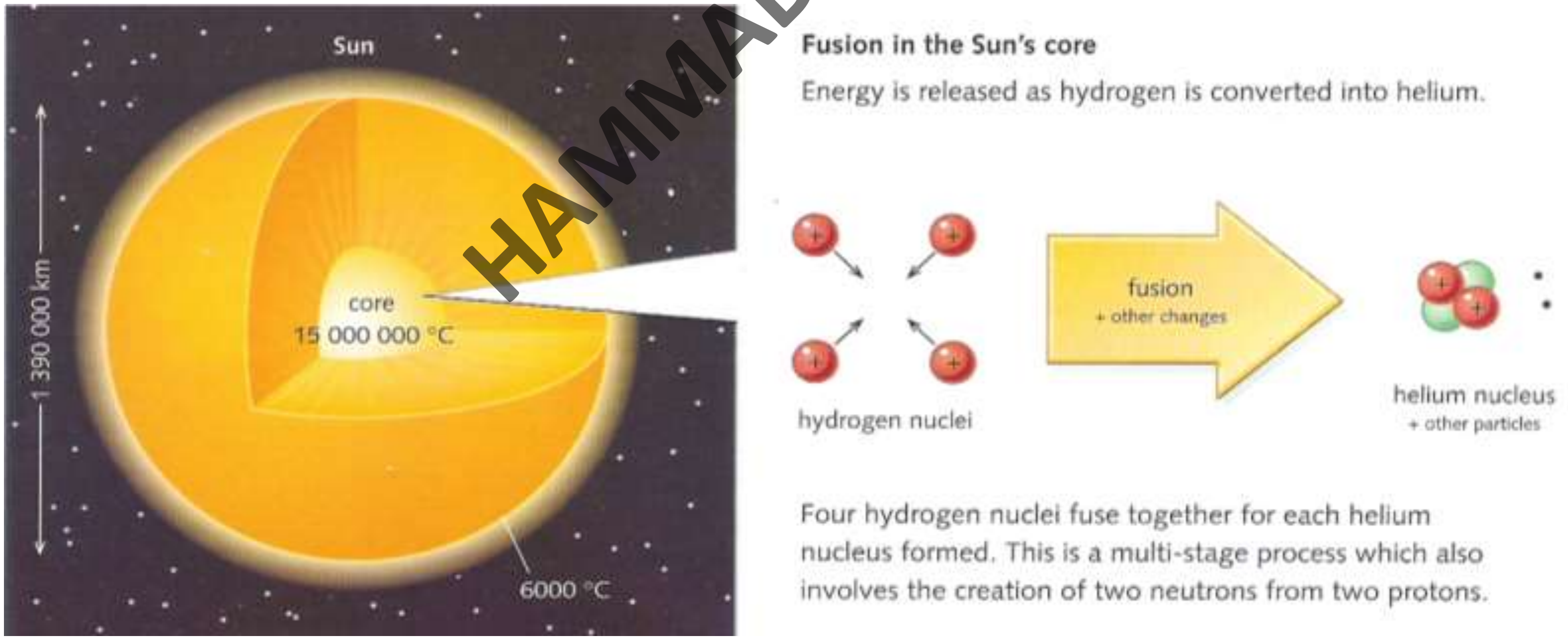
Discuss theories of star formation and their energy production by fusion.

Stars Formation

- Stars are the most widely recognized astronomical objects, and represent the most fundamental building blocks of galaxies.
- Stars form when enough dust and gas clump together because of gravitational forces.
  - *Gravity* pulls the dust and gas together.
  - As the gas falls together, it gets hot.
  - A star forms when it is hot enough for nuclear reactions to start.
  - This releases energy, and keeps the star hot.

Stars Energy Source

- The Sun and other stars use nuclear fusion to release energy.
- During most of a star's lifetime, hydrogen nuclei fuse together to form helium nuclei.



1. Which line in the table describes the nature of an α-particle and of a γ-ray?

	α-particle	γ-ray
A	helium nucleus	electromagnetic radiation
B	helium nucleus	electron
C	proton	electromagnetic radiation
D	proton	electron

A

2. What is a β-particle and from which part of a radioactive atom is it emitted?

	β-particle	emitted from
A	electron	nucleus
B	electron	outer orbits
C	helium nucleus	nucleus
D	helium nucleus	outer orbits

A

3. Which row describes the properties of α-particles?

	ionizing effect	radiation stopped by aluminium?
A	large	no
B	large	yes
C	small	no
D	small	yes

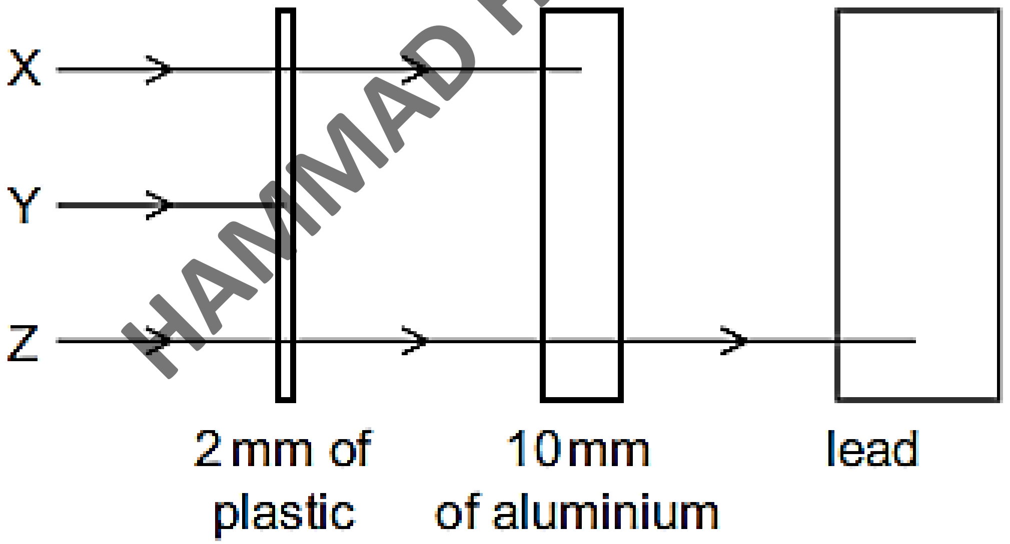
B

4. Which is the correct comparison of the penetrating power and ionising power of alpha-particles and gamma radiation?

	greater penetrating power	greater ionising power
A	alpha	alpha
B	alpha	gamma
C	gamma	alpha
D	gamma	gamma

C

5. The diagram shows the paths of three different types of radiation, X, Y and Z.

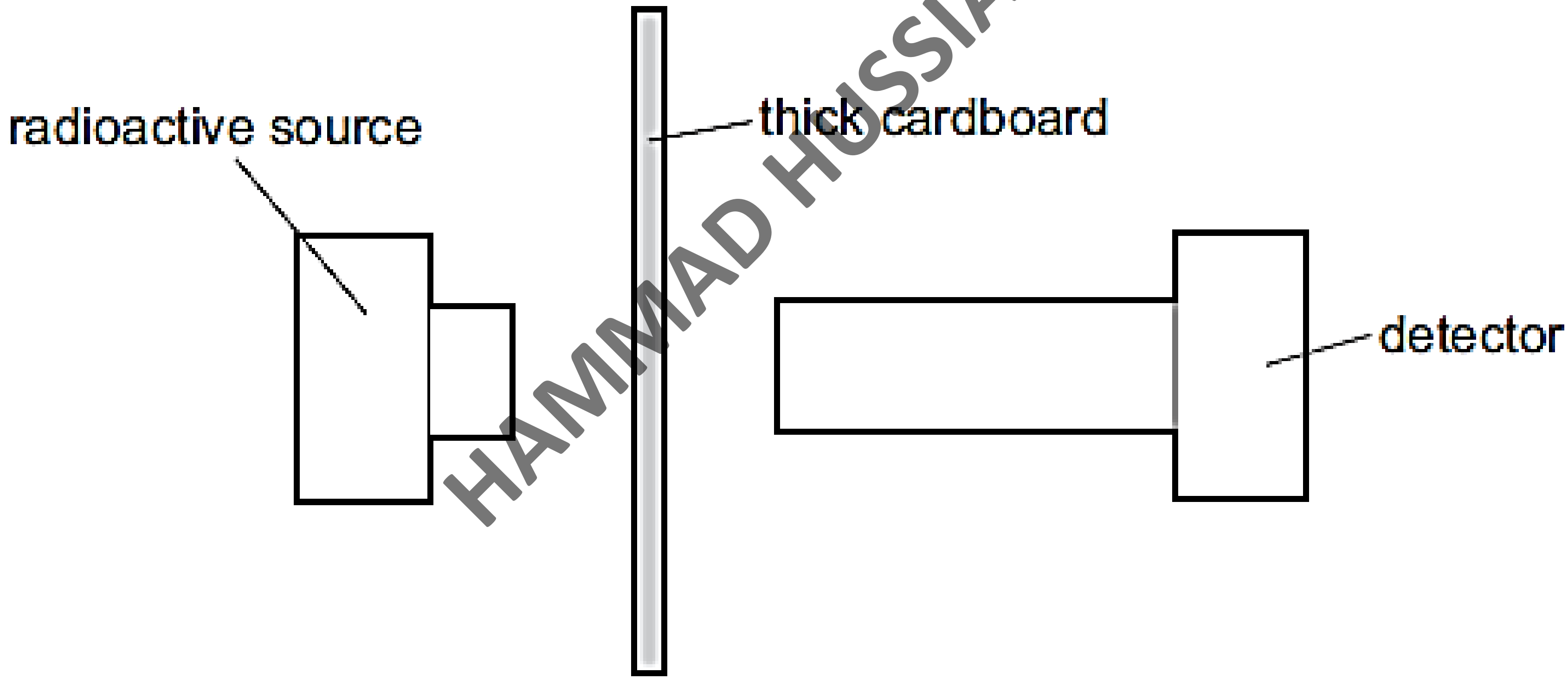


Which row in the table correctly identifies X, Y and Z?

	X	Y	Z
A	α-particles	β-particles	γ-rays
B	β-particles	α-particles	γ-rays
C	β-particles	γ-rays	α-particles
D	γ-rays	α-particles	β-particles

B

6. A student investigates a radioactive source that emits only alpha-particles. Without any source nearby, the detector shows a low reading.
The source and thick cardboard are placed near the detector, as shown.

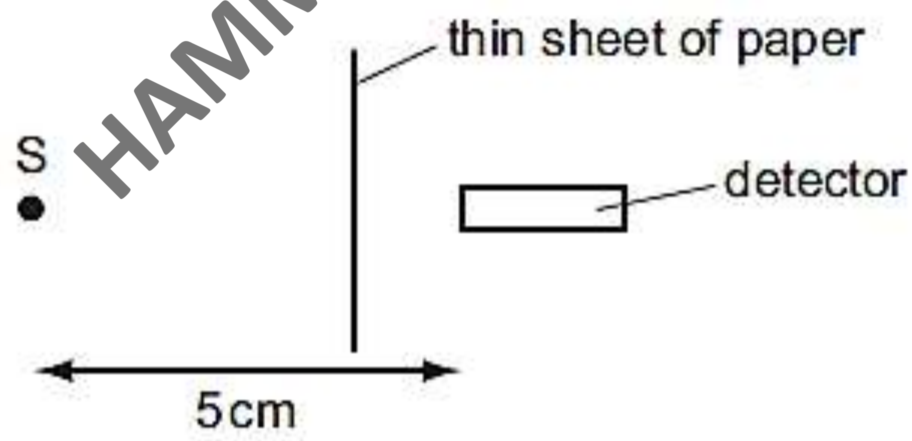

radioactive source
thick cardboard
detector

What is the reading on the detector now, and why?

	detector reading	reason
A	low	background radiation is detected
B	low	some alpha-particles pass through cardboard
C	zero	alpha-particles are all absorbed by the cardboard
D	zero	background radiation is all absorbed by the cardboard

A

7. S is a radioactive source emitting α-particles, β-particles and γ-rays. A detector is placed 5 cm away from S. A thin sheet of paper is placed as shown in the diagram.



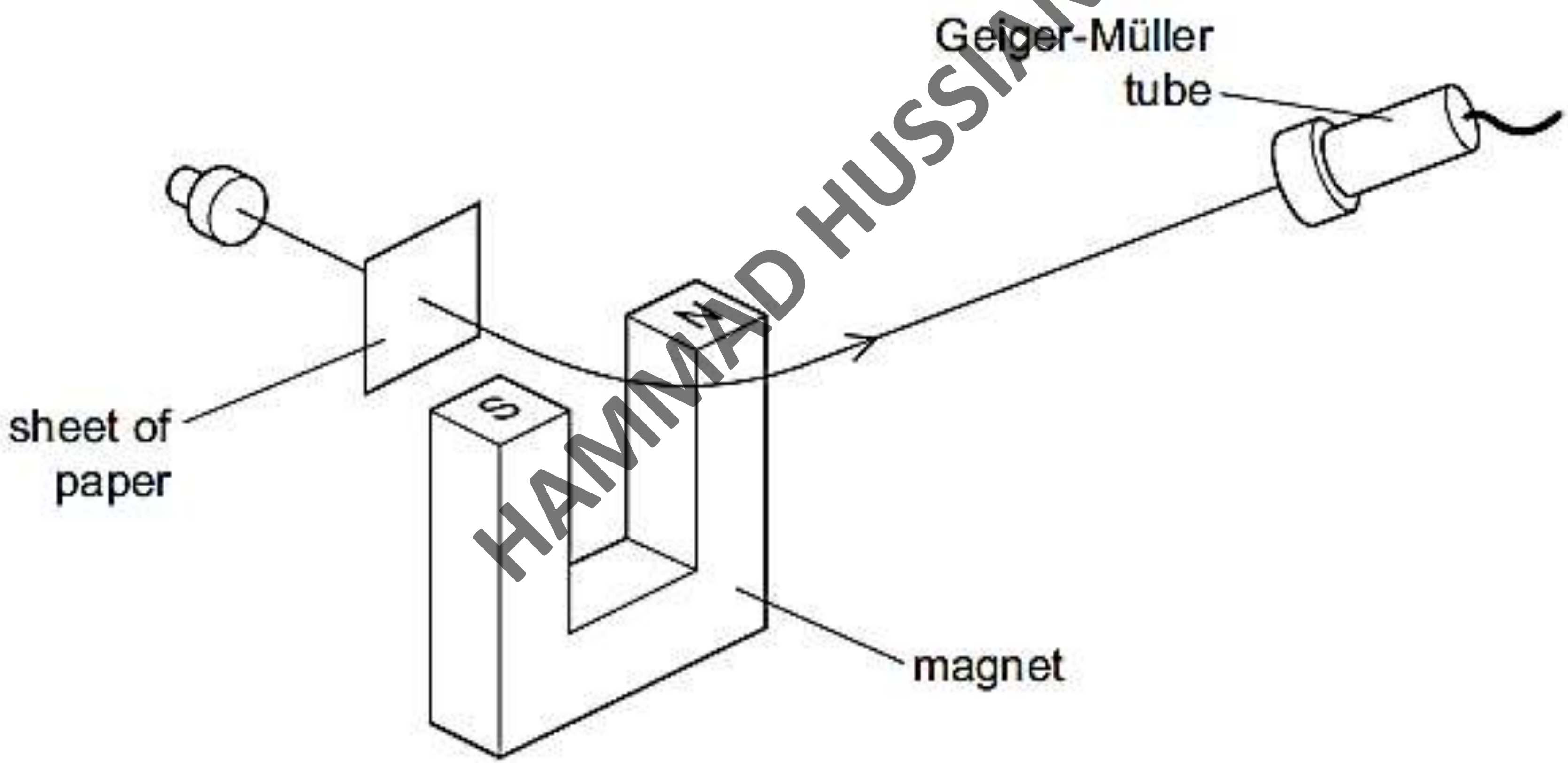
Which radiations can be detected?

A. α-particles and β-particles only
B. α-particles and γ-rays only
C. β-particles and γ-rays only
D. α-particles, β-particles and γ-rays

8. Which travels in a straight line across a magnetic field?

A. alpha-particle
B. electron
C. gamma-ray
D. proton

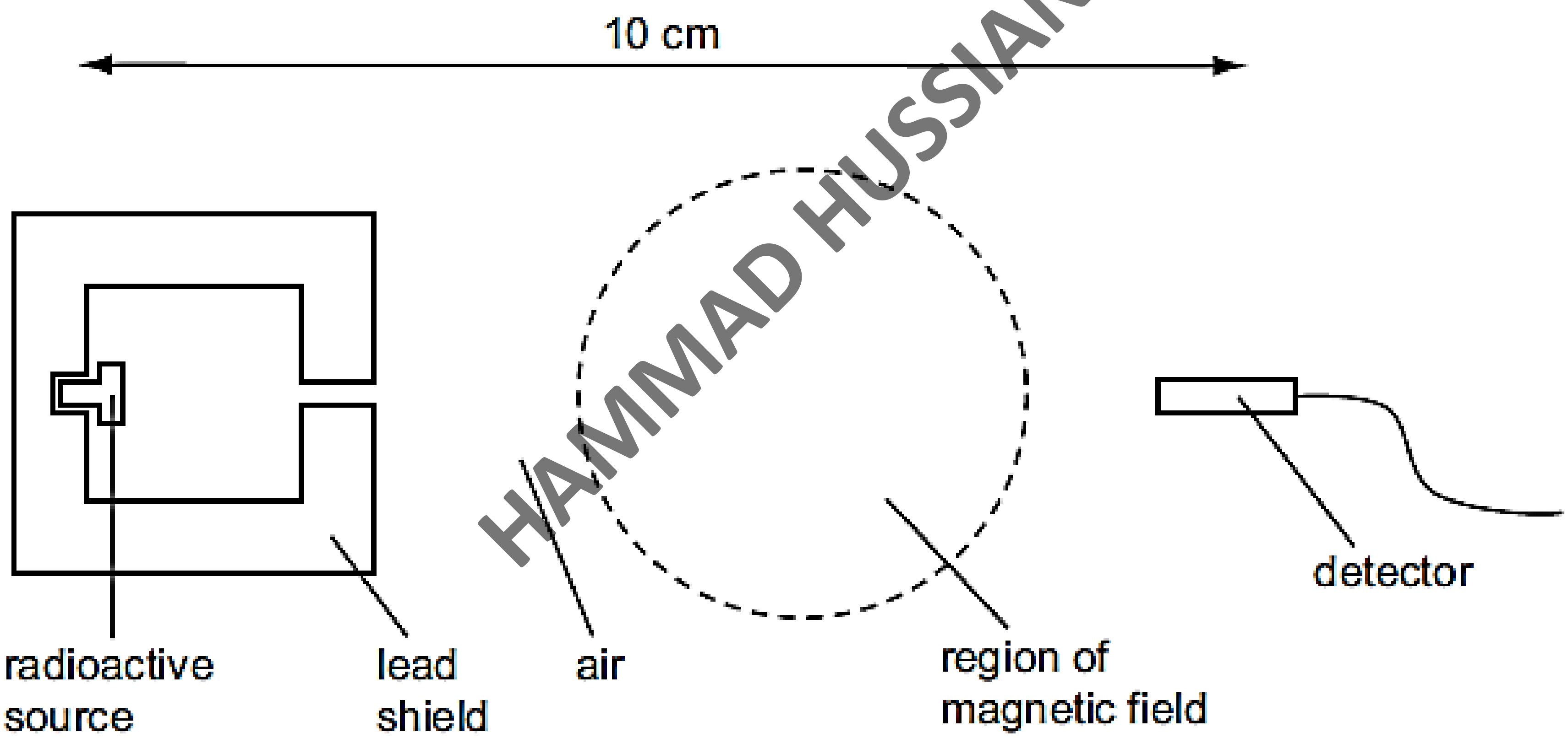
9. A radioactive source emits alpha-particles, beta-particles and gamma-rays. A Geiger-Müller tube and counter detect the emissions, which pass through a thin sheet of paper and a strong magnetic field.


Geiger-Müller
tube
sheet of
paper
S
N
magnet

What is detected by the Geiger-Müller tube?

A. alpha-particles and beta-particles
B. alpha-particles only
C. beta-particles and gamma-rays
D. beta-particles only

10. A student investigates the emission from an unknown radioactive source. The source is 10 cm in front of a detector. A strong magnetic field between the source and the detector is then switched on.


10 cm
radioactive
source
lead
shield
air
region of
magnetic field
detector

The results are shown.

	average count per minute
without magnetic field	4500
with magnetic field	2000
background radiation	50

Which radioactive source produced these results?

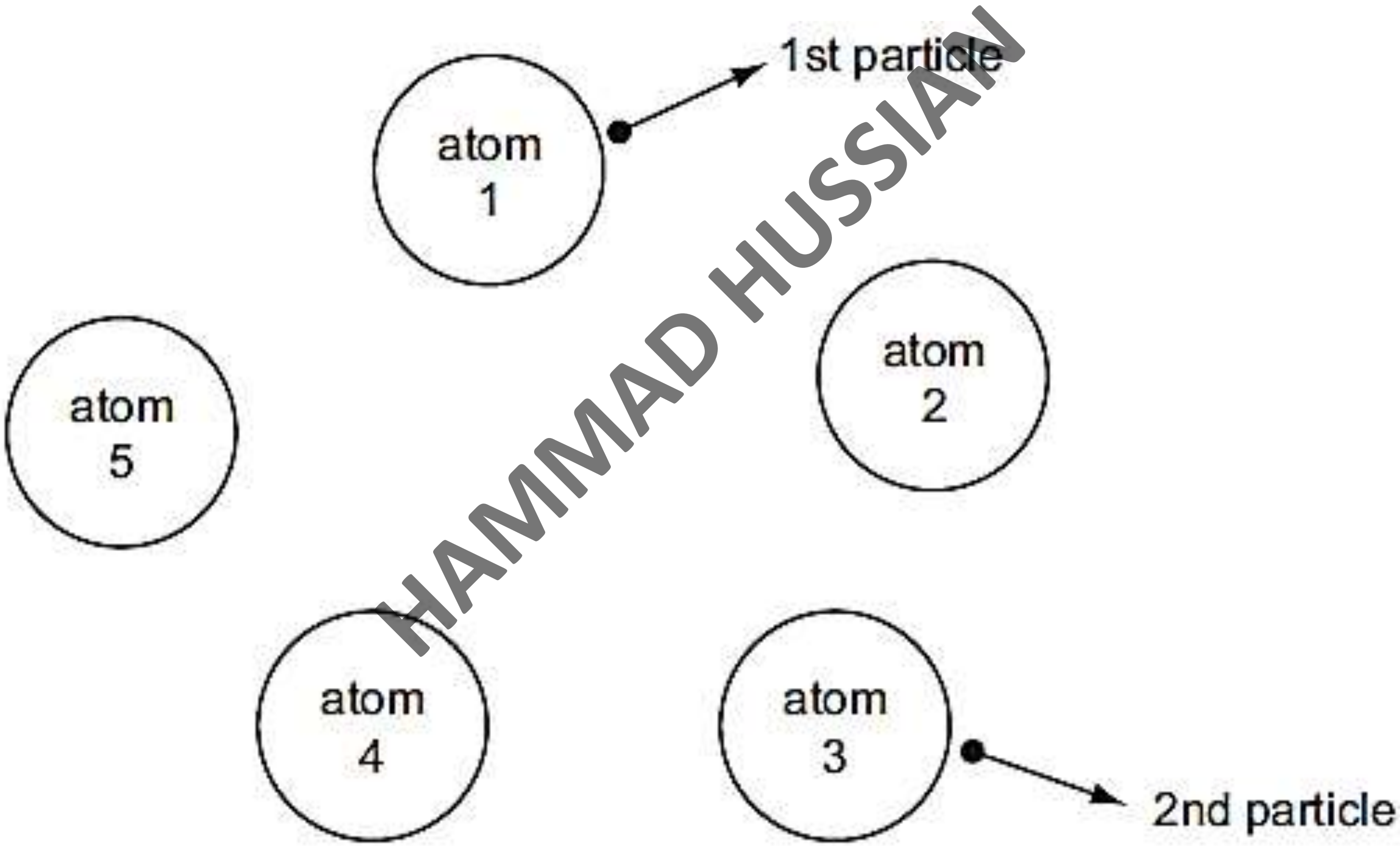
source	emissions from source
A	alpha-particles and gamma-rays only
B	beta-particles only
C	beta-particles and gamma-rays only
D	gamma-rays only

C

11. Which statement is true for all three types of radioactive emission (alpha-particles, beta-particles and gamma-rays)?

A. They are completely absorbed by a thin aluminium sheet.
B. They are deflected by electric fields.
C. They emit light.
D. They ionise gases.

12. The diagram shows five atoms in a radioactive substance. The atoms each give out an α-particle.


1st particle
atom
1
atom
2
atom
5
atom
4
atom
3
2nd particle

Atom 1 is the first to give out a particle.
Atom 3 is the second to give out a particle.
Which atom will give out the next particle?

A. atom 2
B. atom 4
C. atom 5
D. impossible to tell

13. What occurs in the decay of a radioactive nucleus?

A. The nucleus absorbs another nucleus.
B. The nucleus absorbs at least one form of radiation.
C. The nucleus always splits into two equal fragments.
D. The nucleus emits at least one form of radiation.

14. A uranium nucleus $^{238}_{92}U$ emits an α-particle. What are the new nucleon and proton numbers?

	nucleon number	proton number
A	238	88
B	236	90
C	234	92
D	234	90

D

15. A nucleus is represented by ${}^{230}_{91}Z$. It emits one alpha-particle and then one beta-particle. What is the resulting nucleus X?

A ${}^{226}_{88}X$ B ${}^{226}_{89}X$ C ${}^{226}_{90}X$ D ${}^{230}_{89}X$

C

16. In one radioactive decay, radium (Ra) gives rise to radon (Rn) as shown.

$$^{226}_{88}\text{Ra} \rightarrow \, ^{222}_{86}\text{Rn}$$

What particle is also produced?

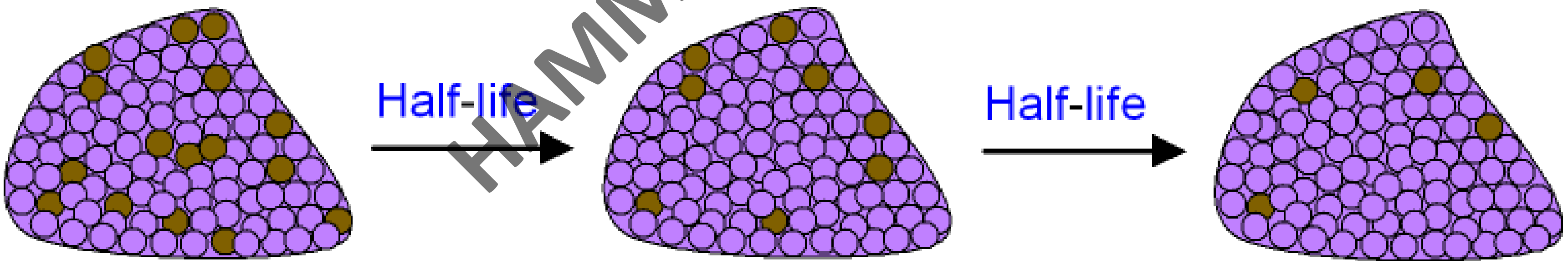
A. an alpha-particle
B. a beta-particle
C. both an alpha-particle and a beta-particle
D. no particle but only gamma-rays

Half-life

Explain what is meant by the term *half-life*.

Half-Life

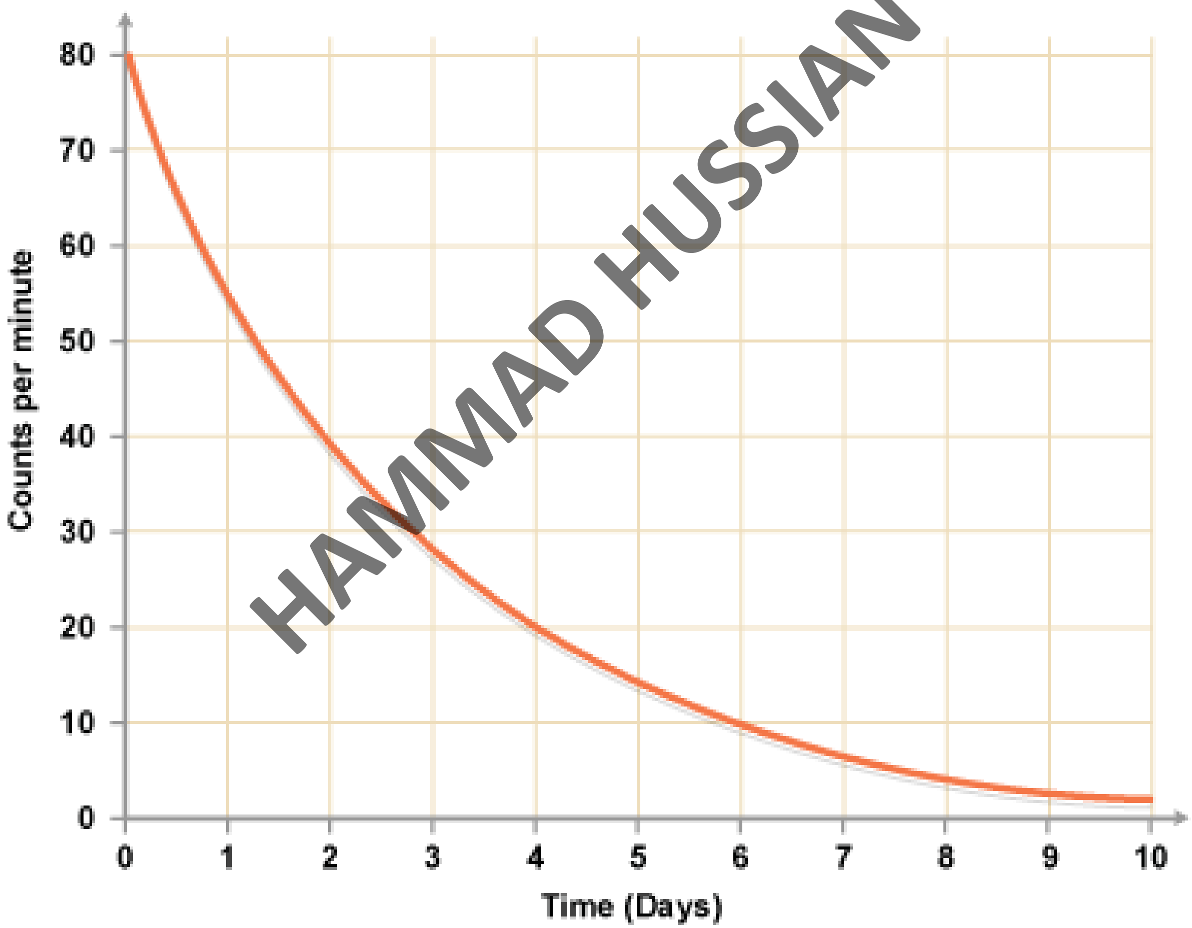
- Half-life is the time taken for half of radioactive nuclei to decay.
- It is also define as the time taken for the count rate to fall to half of its original reading.



Half-life

Make calculations based on half-life which might involve information in tables or shown by decay curves.

Decay Curve



80
70
60
50
40
30
20
10
0
Counts per minute
0
1
2
3
4
5
6
7
8
9
10
Time (Days)

Problem solving

1. A radioactive element has a half-life of 40 minutes. The initial count rate was 1000 per minute. How long will it take for the count rate to drop to (a) 250 per minute and (b) 125 per minute?
2. A radiation counter is set up and a background count of 20 counts per minute is recorded. A radioactive sample is placed less than a centimetre from the detector and the counter then records 820 counts per minute. After 20 min, the count rate falls to 420 counts per minute. What would you expect the count rate to be 60 min after placing the radioactive sample in front of the detector.

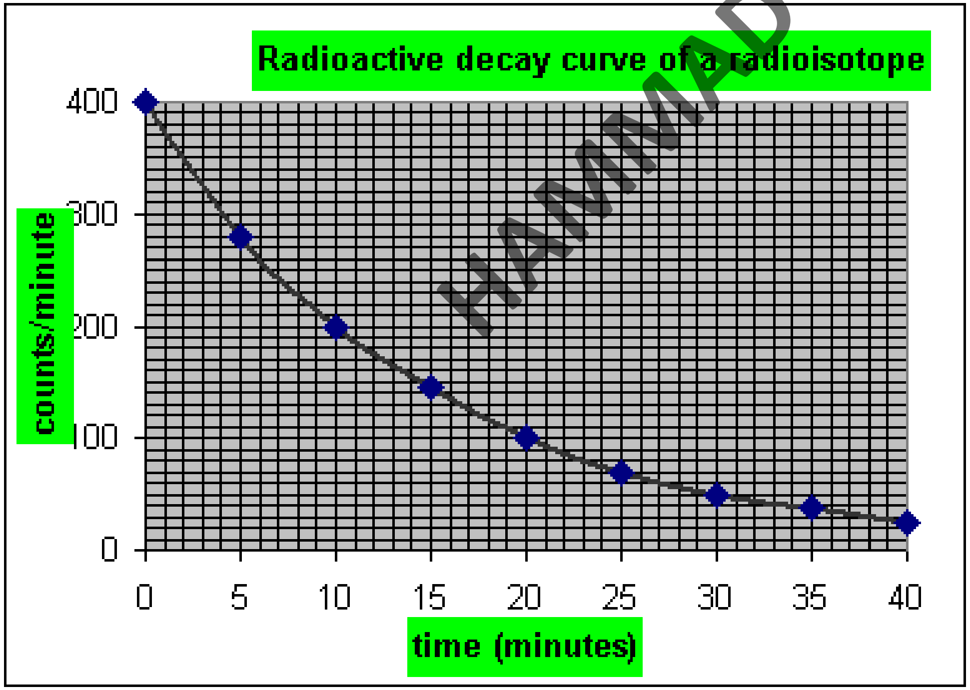
3. The half-life of a radioactive element is 4 days. How long does it take for 20 g for a sample of the radioactive element to decay to 5 g.
4. A radioactive element has a half-life of 5 days. If the mass of a sample of the element is 32 g, what mass of the element is left after 20 days?
5. The table below shows how the activity of a radioactive source varies with time as recorded using a G-M tube and ratemeter.

Time (minute)	0	10	20	30	40	50	60
Counts per minute	4000	2800	2000	1440	1000	720	500

Determine the half-life of the radioactive source.

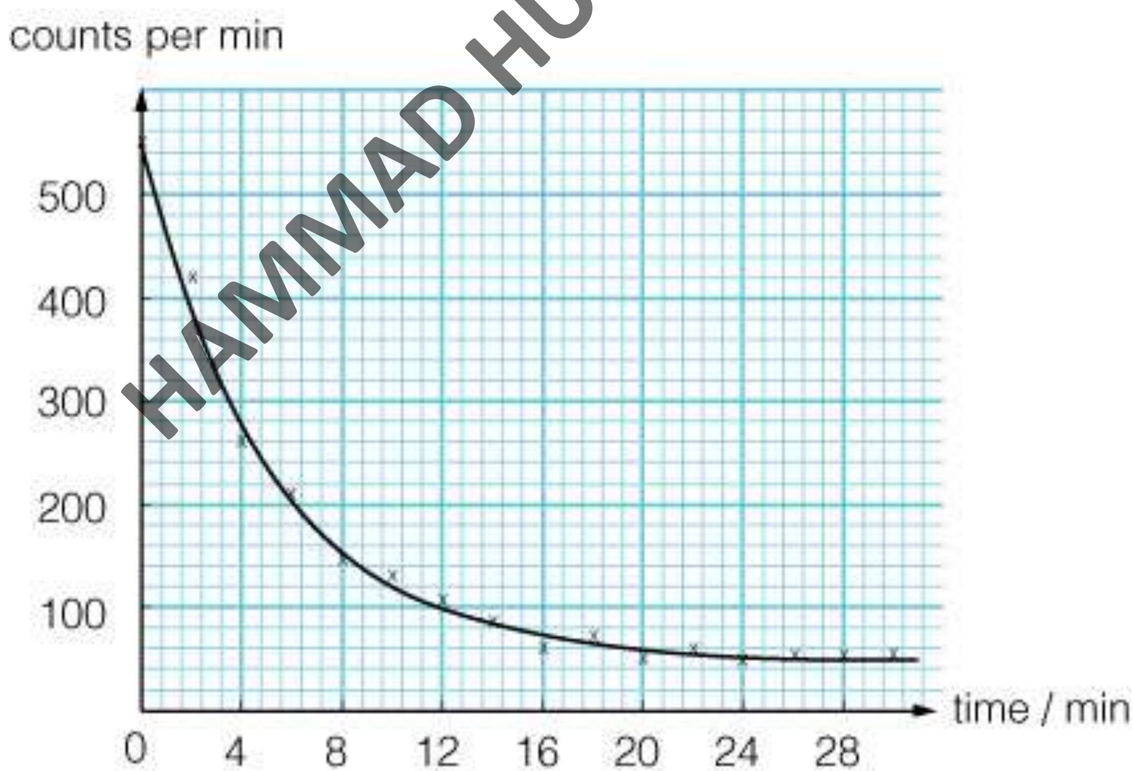
6. Radioisotopes Y has a half-life of 2000 years. How long will it take the activity of a sample Y to decrease to one-eight of its initial value?
7. A sample radioactive substance contains 200 undecayed atoms. How many will remain after 3 half-lives?
8. A radioactive source has a half-life of 30 minutes. What fraction is left after 2 hours?

9. The graph shows the rapid decay of a very unstable radioactive isotope in terms of count rate per minute (cpm) versus minutes.



From the graph determine the time it takes for half of the radioactive atoms to decay.

10. Determine the half-life of a nuclide from a decay curve.



Uses of radioactive isotopes including safety precautions

Describe how radioactive materials are moved, used and stored in a safe way.

Handling Radioactive Material

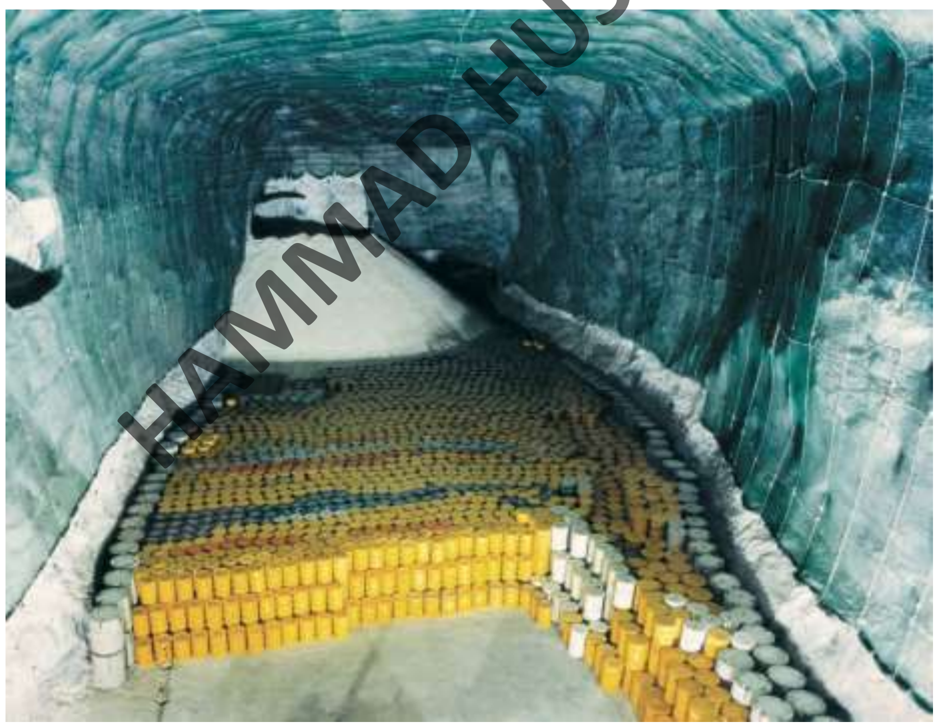
- We cannot do much to reduce our exposure to natural background radiation, but great care is needed when handling radioactive materials. Precautions include:

- wearing protective clothing

- keeping as far away as is practicable - for example, by using tongs or robotic arms.

- keeping radioactive materials in lead-lined containers, labelled with the appropriate hazard symbol.

- keeping your exposure time as short as possible



Uses of radioactive isotopes including safety precautions

Discuss the way in which the type of radiation emitted and the half-life determine the use for the material.

Medical Tracer

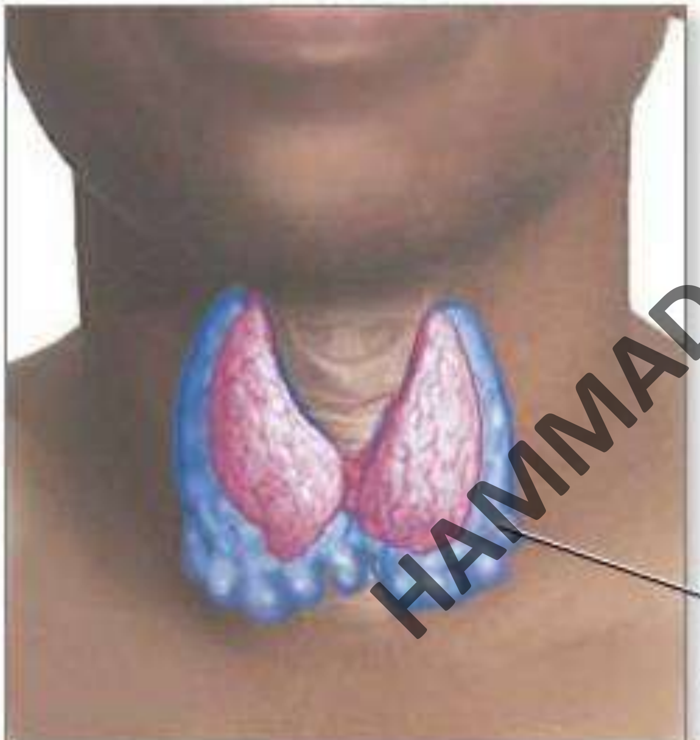
- A radioactive isotope is introduced into a living system, where it flows along the bloodstream, following the path of chemical processes therein.
- It is easily detected using a scanner or Geiger counter. The scanner take pictures and are run together in rapid succession, giving physicians a movie-like view of the isotope's path.
- When the procedure is finished the isotope is flushed out of the body along with other waste products.

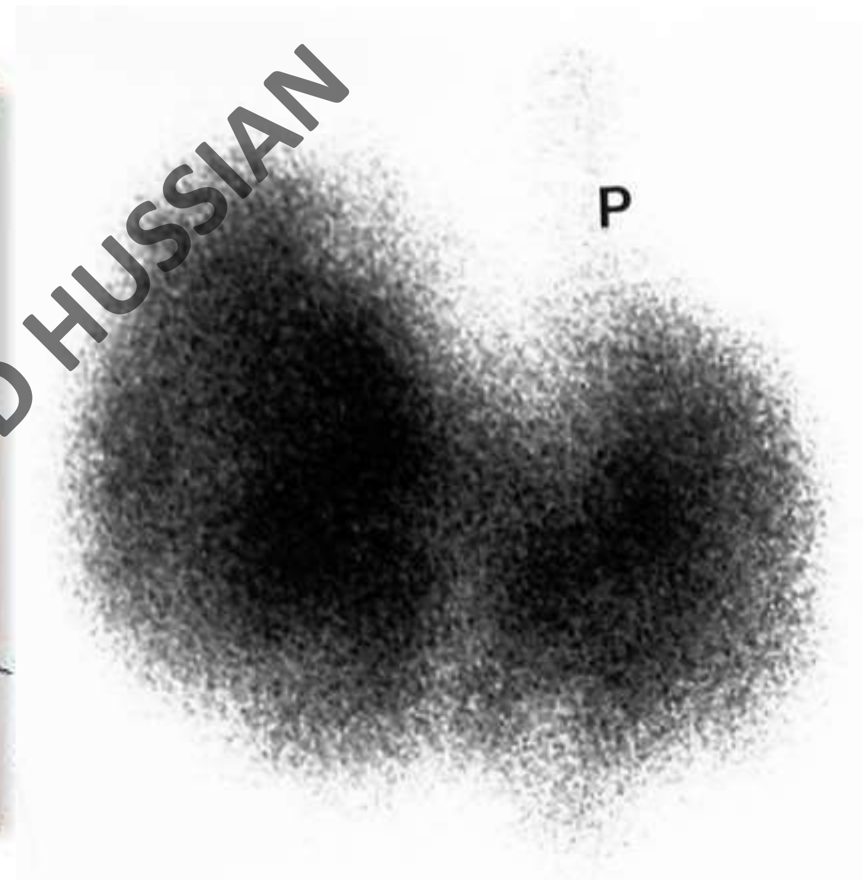

The radiotracer, injected into a vein, emits gamma radiation as it decays. A gamma camera scans the radiation area and creates an image.
Gamma camera

Iodine-131

- A common procedure is the injection of iodine-131 for the observation of the thyroid gland.
- A healthy thyroid will accumulate any iodine entering the body.
- When a physician scans the patient, if iodine-131 is present in the thyroid, the gland is working properly.
- However, if the trace element has not collected in the thyroid, the physician knows the gland is failing.

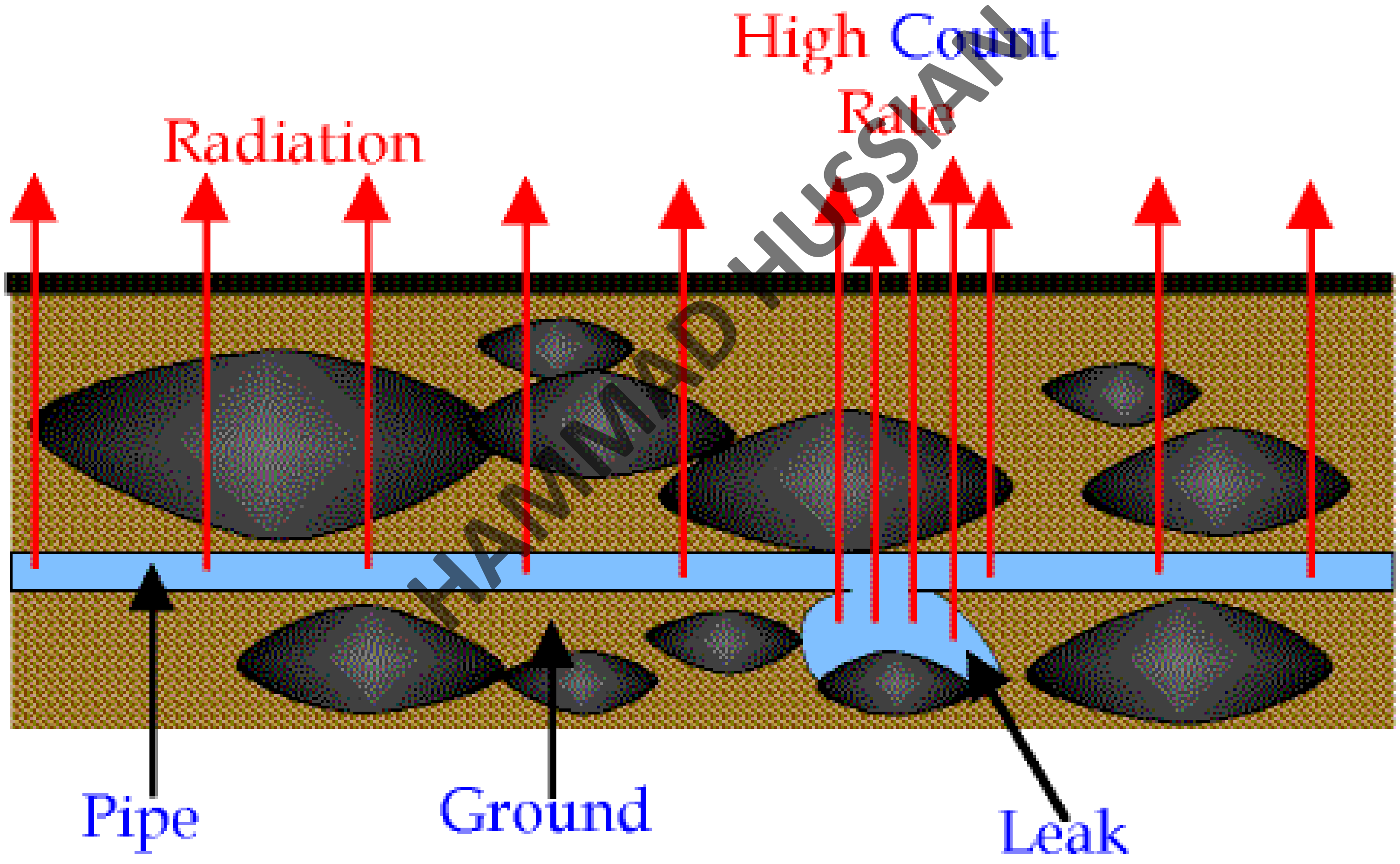
Hashimoto's disease





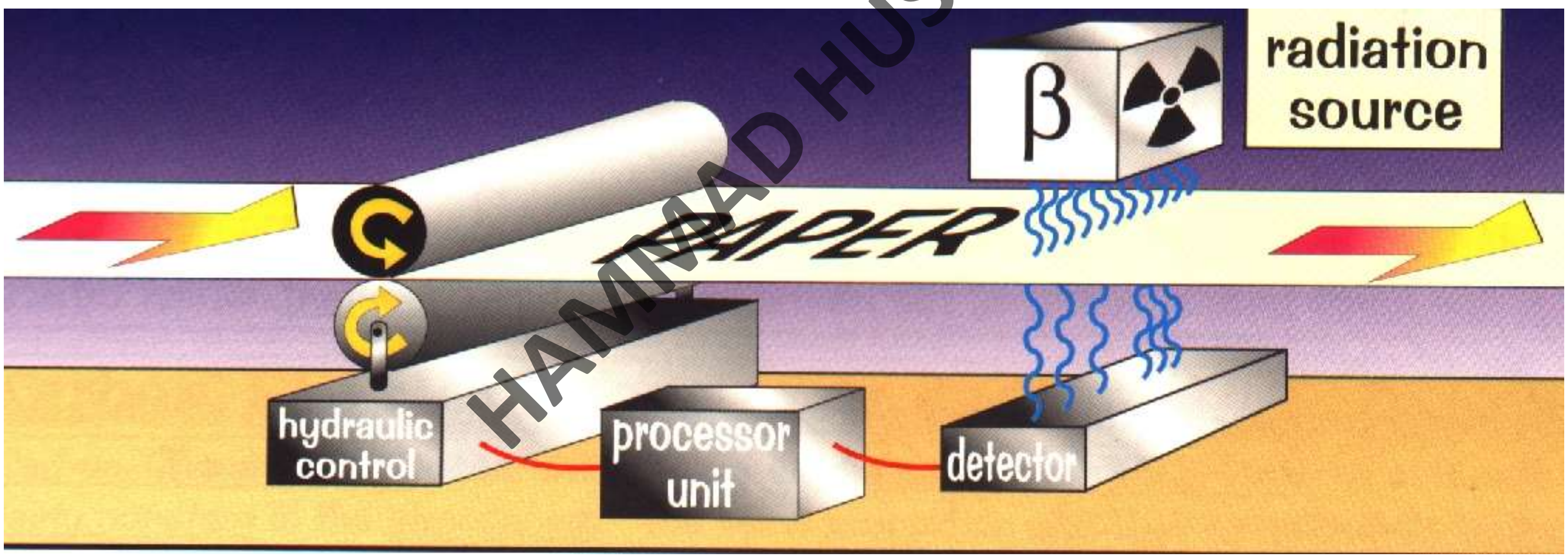
Leak Detector

- A method for determining the position of a leak in a conduit or pipeline.
- Short-lived radioisotope is inserted into the conduit or pipeline and is caused to move along it by pressuring up the conduit or pipeline from one or both ends thereof with fluid, for example water.
- The carrier body travels to the leak but no further and its location is detected from outside the conduit or pipeline using a radiation detector.


High Count
Rate
Radiation
Pipe
Ground
Leak

Manufacturing

- A source of beta radiation is used to pass beta particles through the paper.
- A detector on the other side of the paper detects the beta particles that pass through.
- The detector is connected to a hydraulic control via a processor unit.
- If the radiation level detected drops it means the paper is too thick so the hydraulic control pushes rollers closer together in order to reduce the paper thickness.
- If the radiation level detected increases it means the paper is too thin so the hydraulic control pulls the rollers apart so the paper thickness can be increased.


radiation
source
β
PAPER
hydraulic
control
processor
unit
detector

Uses of radioactive isotopes including safety precautions

Discuss the origins and effect of background radiation.

Uses of radioactive isotopes including safety precautions

Discuss the dating of objects by the use of ^{14}C.

Carbon Dating

- Radiocarbon dating uses the amount of Carbon 14 (C14) available in living creatures as a measuring stick.
- All living things maintain a content of carbon 14 in equilibrium with that available in the atmosphere, right up to the moment of death. When an organism dies, the amount of C14 available within it begins to decay at a half life rate of 5700 years
- Comparing the amount of C14 in a dead organism to available levels in the atmosphere, produces an estimate of when that organism died.

Problem Solving

Carbon-14 has a half-life of 5700 years.

1. Cro-Magnon man is one of our ancestors. Five adult skeletons were found near Les Eyzies in France. A 1 g sample of charcoal from this site produced a radioactive count of 0.5 counts per minute. A modern sample of charcoal of same mass produces a count rate of 32 counts per minute. Both counts were corrected for background radiation. How long ago did Cro-Magnon man live?
2. A 10-g sample of wood cut recently from a living tree has an activity of 160 counts/minute. A piece of charcoal taken from a prehistoric campsites also weighs 10 g but has an activity of 40 counts/minute. Estimate the age of the charcoal.

3. A wooden post from an archaeological dig produces 150 counts per minute. Wood from an identical species of tree currently alive gives 600 counts per minute. How long ago did the wood from the archaeological dig die?
4. In a carbon-dating experiment a sample of wood from an object was burnt and the carbon dioxide produced was collected. The activity of the carbon dioxide was equivalent to 2.25 count per minute per gram of carbon. When the same experiment was repeated using wood from a modern source, the corrected counts was 18 count per minute per gram of carbon. What is the likely age of the find?

Uses of Carbon Dating

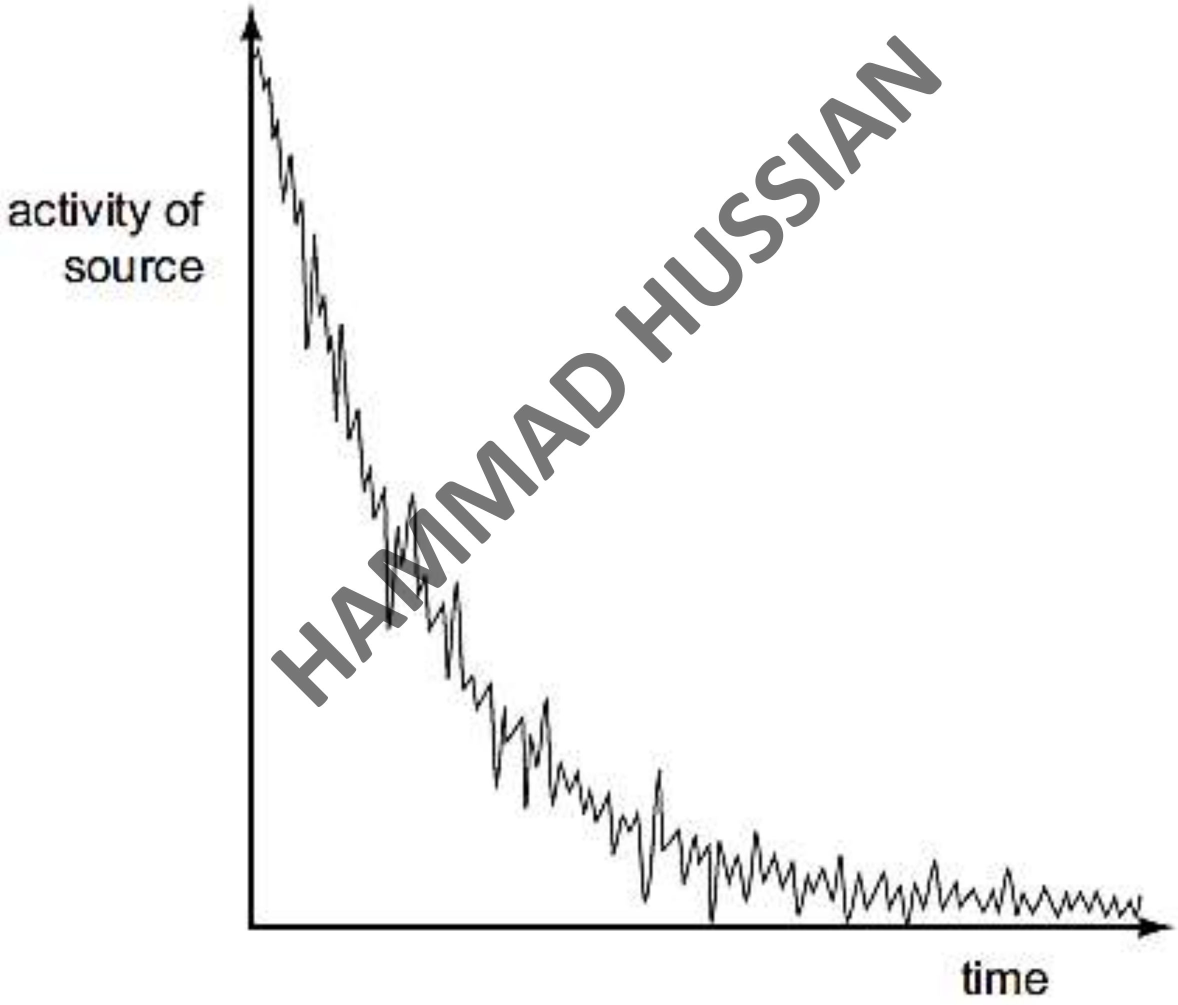
- Carbon dating can be used on anything which used to be alive.
- Examples are
  - Animal (or human) remains, including skin, fur and bone.
  - Plant remains, including wood, natural fibres (cotton, silk, wool, cloth, rope), seeds and pollen grains.
  - Some fossils can be dated this way if they still contain some of the original carbon of the plant or animal.

Limitations of Carbon Dating

- Carbon dating cannot be used on things which have never lived.
  - Examples are brick, rock and metal.
- The amount of carbon-14 in samples is very small and after 9 or 10 half-lives the amount of radioactivity which is emitted by the sample is too tiny for an accurate count rate to be measured.
  - Therefore carbon dating cannot be used to date samples which are more than 50,000 to 60,000 years old.
- The method of carbon dating uses an assumption that the amount of carbon-14 present in the past is the same as that present in the environment today.

1. A sample of radioactive isotope is decaying. The nuclei of which atoms will decay first?
   A. impossible to know, because radioactive decay is random
   B. impossible to know, unless the age of the material is known
   C. atoms near the centre, because they are surrounded by more atoms
   D. atoms near the surface, because the radiation can escape more easily

2. The activity of a radioactive source is measured over a period of time. The graph shows the decay curve.


activity of
source
time

Why is the curve not smooth?

A. Background radiation has not been subtracted.
B. Radioactive decay is a random process.
C. The half-life is not constant.
D. The temperature is changing.

3. Which statement explains the meaning of the half-life of a radioactive substance?

A. half the time taken for half the substance to decay

B. half the time taken for the substance to decay completely

C. the time taken for half the substance to decay

D. the time taken for the substance to decay completely

4. A sample of radioactive uranium has mass 1 g. Another sample of the same material has mass 2 g.
Which property is the same for both samples?

A. the amount of radiation emitted per second
B. the half-life
C. the number of uranium atoms
D. the volume

5. A powder contains 400 mg of a radioactive material that emits α-particles.
The half-life of the material is 5 days.
What mass of that material remains after 10 days?

A. 0 mg
B. 40 mg
C. 100 mg
D. 200 mg

6. A radioactive substance has a half-life of 2 weeks. At the beginning of an investigation the substance emits 3000 β-particles per minute. How many β-particles will it emit per minute after 6 weeks?

   A. 0
   B. 375
   C. 500
   D. 1500

7. The half-life of a radioactive material is 24 years.
The activity of a sample falls to a fraction of its initial value after 72 years.
What is the fraction?

A. 1/3
B. 1/4
C. 1/6
D. 1/8

8. The half-life of a radioisotope is 2400 years. The activity of a sample is 720 counts / s. How long will it take for the activity to fall to 90 counts / s?

   A. 300 years
   B. 2400 years
   C. 7200 years
   D. 19 200 years

9. The half-life of a radioactive substance is 5 hours. A sample is tested and found to contain 0.48 g of the substance.
   How much of the substance was present in the sample 20 hours before the sample was tested?
   A. 0.03 g
   B. 0.12 g
   C. 1.92 g
   D. 7.68 g

10. A radioactive element has a half-life of 70 s. The number of emissions per second, N, of a sample of the element is measured at a certain time.
What was the number of emissions per second 70 s earlier?

A. 0
B. N / 2
C. N
D. 2N

11. The count-rate from a radioactive source falls from 400 to 50 in 3.0 minutes. What is the half-life?

A. 0.75 minutes
B. 1.0 minutes
C. 2.7 minutes
D. 8.0 minutes

12. A detector is used to measure the count-rate near a radioactive source. The reading is 4000 counts per minute. After 30 minutes the count-rate has fallen to 500 counts per minute. What is the half-life of the radioactive source? You may ignore the effects of background radiation.

A. 3 minutes
B. 5 minutes
C. 6 minutes
D. 10 minutes

13. The count rates of four radioactive sources were measured at the same time on three consecutive days.
Which source has a half-life of two days?

	Monday	Tuesday	Wednesday
A	100	50	25
B	200	140	100
C	300	300	300
D	400	200	100

B

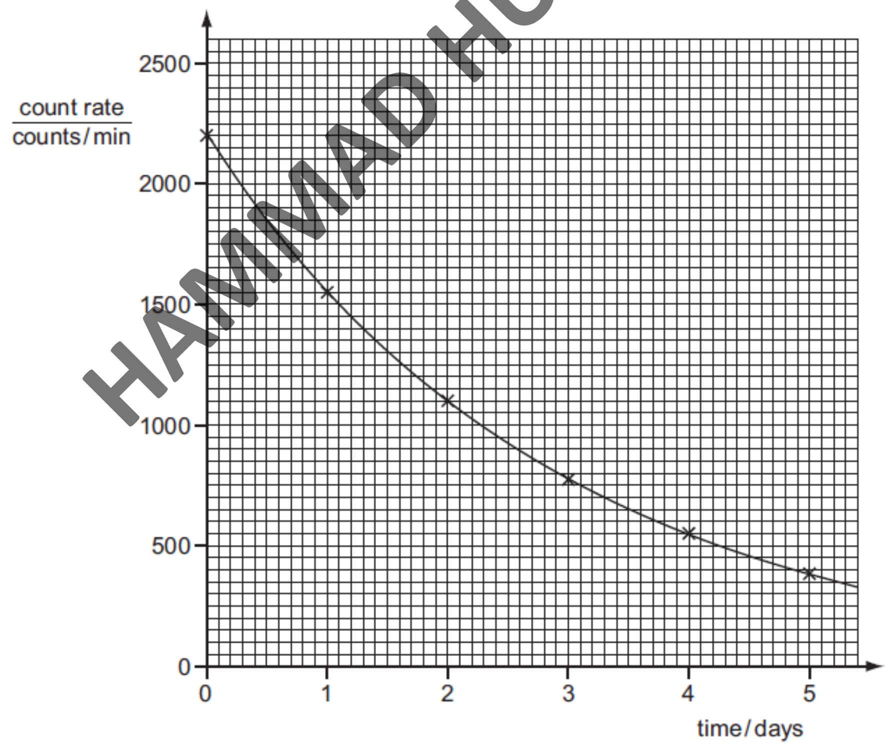
14. The table shows details of two samples of radioactive nuclides X and Y.

nuclide	number of radioactive atoms at time = 0	half-life
X	16 000	1 day
Y	2 000	2 days

After how many days will the number of atoms of nuclide X be equal to the number of atoms of nuclide Y?

A. 2 days
B. 4 days
C. 6 days
D. 8 days

15. The graph shows the decay curve for one particular radioactive nuclide.



What is the half-life of this nuclide?

A. 1.0 day
B. 1.5 days
C. 2.0 days
D. 2.5 days

16. Which row is correct for fission and for fusion?

	fission of a nucleus	fusion
A	produces larger nuclei	is the energy source of a star
B	produces larger nuclei	is used to release energy in a power station
C	produces smaller nuclei	is the energy source of a star
D	produces smaller nuclei	is used to release energy in a power station

C

17. Which equation shows a nuclear fission reaction?

A $^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He$

B $^{14}_{7}N$ + neutron $\rightarrow ^{15}_{7}N$

C $^{46}_{21}Sc \rightarrow ^{46}_{21}Sc$ + gamma ray

D $^{239}_{92}U \rightarrow ^{95}_{38}Sr + ^{141}_{54}Xe$ + 3 neutrons

D

18. Which material is commonly used as a lining for a box for storing radioactive samples?

A. aluminium
B. copper
C. lead
D. uranium

19. When dealing with radioactive substances there are possible dangers.
Which statement is correct?

A. Beta-particles can pass through skin and damage body cells.
B. Gamma-radiation is more dangerous than alpha or beta because it has a longer half-life.
C. Materials that emit only alpha-particles must be kept in thick lead containers.
D. Radioactive materials are safe to handle after two half-lives.

20. In the treatment of brain cancer, a patient's head is enclosed in a helmet containing a number of radioactive sources. The radiation from each source is directed towards the cancer.
Which nuclide is the most suitable for these sources?

	nuclide	radiation	half-life
A	caesium-137	gamma	30 years
B	sodium-24	beta	15 hours
C	strontium-90	beta	29 years
D	californium-246	alpha	36 hours

A