the PiXL club
partners in excellence

PiXL Science

PiXL KnowIT!

GCSE Physics

Edexcel Radioactivity

www.pixl.org.uk

The PiXL Club Ltd, Company number 07321607

Overview
Edexcel Topic 6

Radioactivity

Part 1

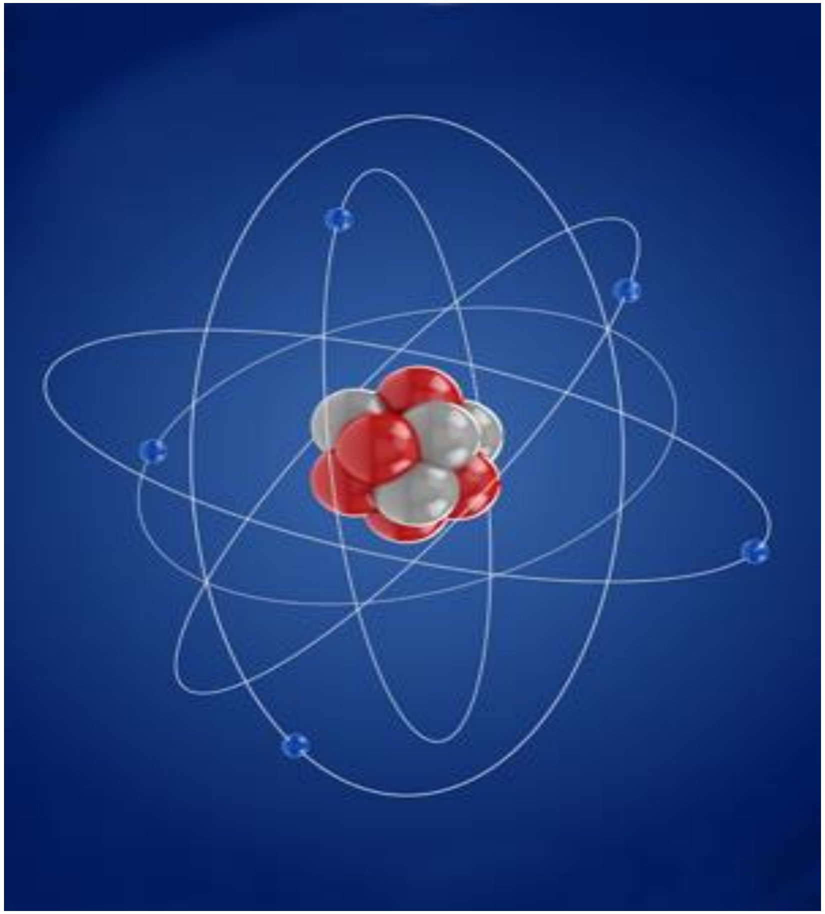
- Atoms
- Types of radiation
- Background radiation

Part 2

- Radioactive decay and half life
- Uses and dangers of radioactivity

Part 3

- Nuclear reactions



PiXL
partners in excellence

LearnIT! KnowIT!

Part 1

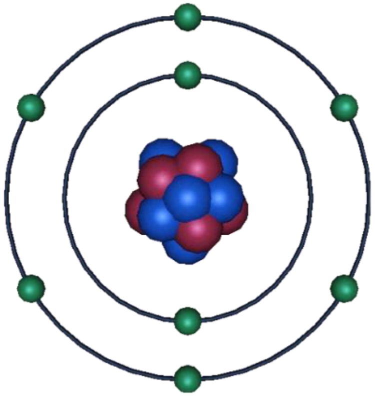
- Atoms
- Types of radiation
- Background radiation

Structure of the atom - subatomic particles

- An **atom** has a positively charged **nucleus** containing **protons and neutrons**, surrounded by negatively charged **electrons in shells**.
- The nuclear radius much smaller than that of the atom and with almost all mass **of an atom** is **concentrated in the nucleus**.
- An atom contains **equal numbers of protons and electrons**.
- Atoms have **no overall electrical charge** because the number of positive protons equals the number of negative electrons.

number of protons = atomic number

- All atoms of an element have the **same number of protons in the nucleus**. This number is **unique to that element**.

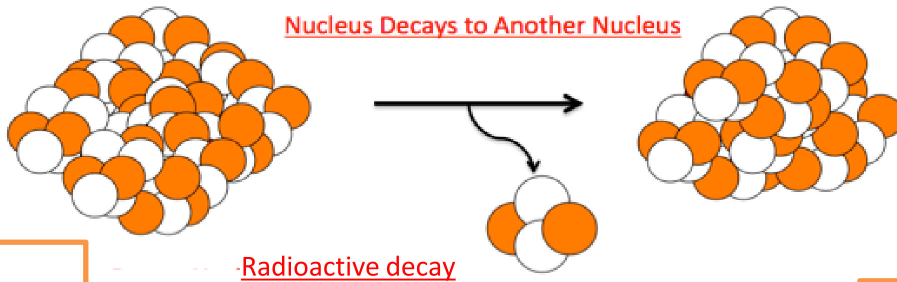


	Mass	Charge	Location
Proton	1	+ (positive)	nucleus
Neutron	1	no charge	nucleus
Electron	1/1835 negligible	- (negative)	shells

Radioactive decay and nuclear radiation

The nuclei of some atoms are unstable. To become more stable these nuclei give out radiation. This process is called radioactive decay.

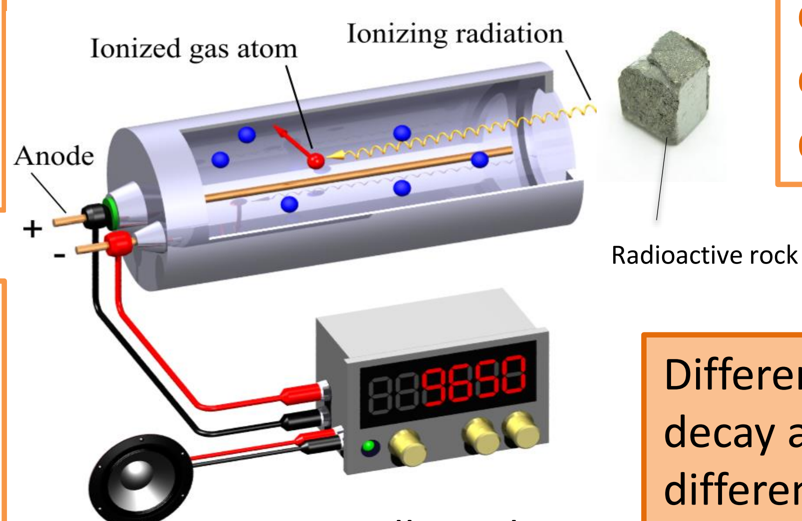
Unstable atom



Stable atom

Activity = **rate at which a source of unstable nuclei decays**, measured in **becquerels (Bq).**

Count-rate = **number of decays recorded each second by a detector**

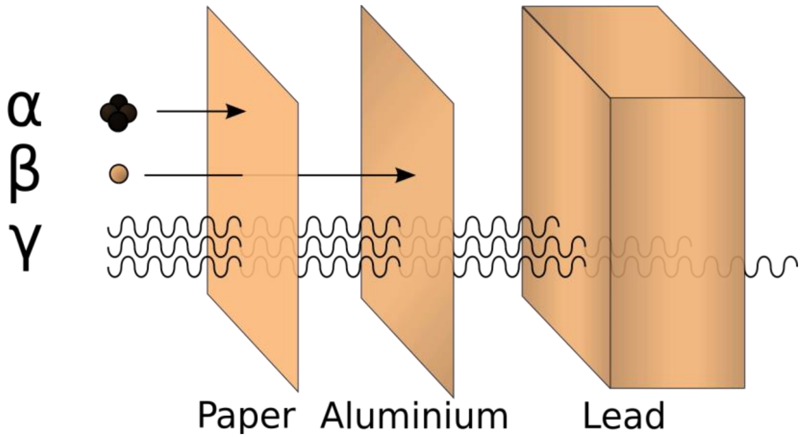


Geiger–Müller tube

Radioactivity can be detected by using Geiger–Müller tube or photographic film.

Different radioactive isotopes decay at different rates and emit different types of radiation.

Properties of alpha, beta and gamma radiation.



Alpha, beta and gamma radiation can penetrate different materials due to their differing nature.

Alpha – easily stopped by **a few sheets of paper**.

Beta – penetrates paper but stopped by a thin **sheet of aluminium**.

Gamma – only stopped by **thick lead** or several metres of **concrete**.

All three types of radiation cause **ionisation** of other atoms. If these atoms are in **living cells** it can cause damage which could lead to **cancer.**

Name	Symbol	Speed	Range in air	Ionising power
Alpha	α	Slowest	6 - 8 cm	High
Beta	β	Medium	1 – 2 m	Medium
Gamma	γ	Fastest	300 - 500 m	Low

PiXL
partners in excellence

LearnIT!
KnowIT!

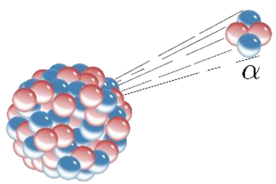
Part 2

- Radioactive decay and half life
- Uses and dangers of radioactivity

Nuclear equations

Nuclear equations show the changes to an atom when it emits radiation.

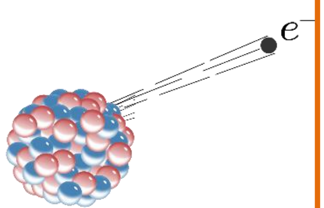
Alpha emission



Nucleus **loses 2 protons** and **2 neutrons**.
Atomic number will reduce by 2 and atomic mass by 4.

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

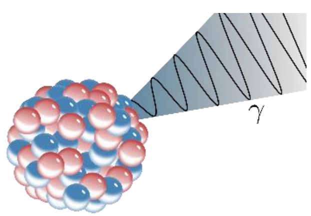
Beta emission



Nucleus **loses an electron** which is produced when a neutron turns into a proton. So **mass stays the same** but **atomic number of the product increases by one**.

$$^{14}_{6}\mathrm{C} \longrightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\mathrm{e}$$

Gamma emission



No particles are emitted so there is **no change to the nucleus**. Atomic mass and atomic number stay the same.

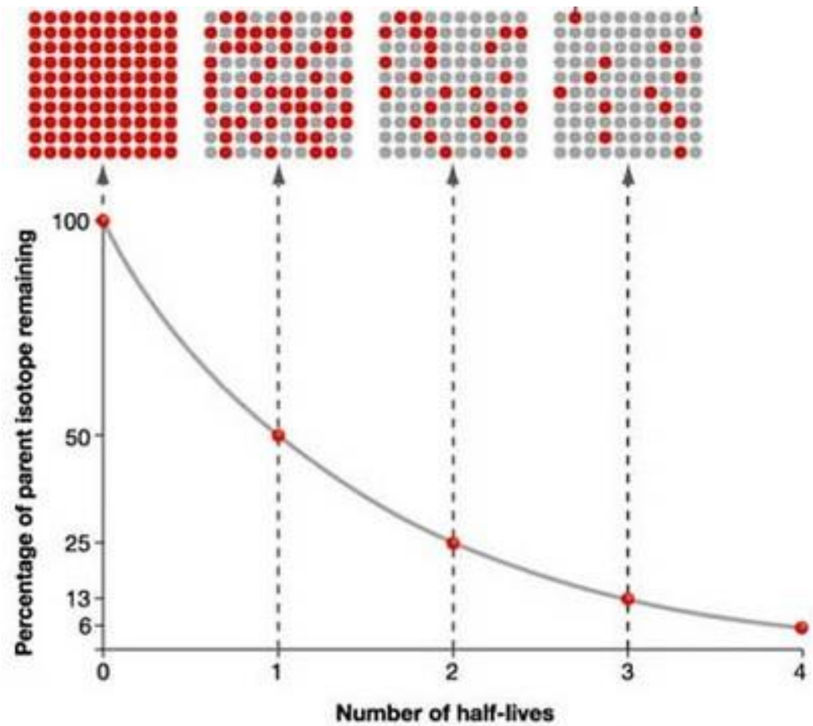
$$^{99}_{43}\mathrm{Tc} \longrightarrow {}^{99}_{43}\mathrm{Tc} + \gamma$$

Half life and the random nature of radioactive decay

Radioactive decay is a random process so the likelihood of a decay taking place is a probability problem. For this reason, the **half-life** of an isotope is given rather than saying how long it will take to fully decay.

The **half-life** of a radioactive isotope is the time it takes for the **number of nuclei** of the isotope in the sample to halve, or the time it takes for the **count rate** from a sample containing the isotope to fall to half its initial level.

The net decline of the isotope is the fraction remaining after a number of half lives.
E.g. 100 → 50 → 25
After 2 half lives net decline is 75/100 = **3/4**



PiXL
partners in excellence

Different half lives of isotopes

Radioactive isotopes have an enormous range of half-lives.

Examples of the range of half-lives of radioactive materials

Radioactive nuclide	Nuclide notation	Half-life
Lithium-8	$^{8}_{3}Li$	0.838 s
Krypton-89	$^{89}_{36}Kr$	3.16 minutes
Sodium-24	$^{24}_{11}Na$	15 hours
Iodine-131	$^{131}_{53}I$	8 days
Cobalt-60	$^{60}_{27}Co$	5.27 years
Radium-228	$^{226}_{88}Ra$	1600 years
Uranium-235	$^{235}_{92}U$	703 million years

Half-life and hazard (Physics only)

Radioactive isotopes with a **short half-life** often give **high doses** of radiation in a short period of time so are often dangerous.

Long half-life isotopes are **low dose** hazards but they are around for a very **long time**. Uranium-238 is the main fuel producer for the nuclear industry but is so slow at emitting radiation it is often considered quite safe by scientists. Products of the nuclear industry such as Iodine-131 are much more dangerous as they emit radiation at a much faster rate and are soluble so they get into the food chain much more easily.

Half life and the random nature of radioactive decay

Calculating the half life of a radioactive isotope.

If you know the start and finish count rate and the time taken, you can calculate the half life.

Example:

The count rate of an isotope is 1008 Bq. This falls to a count rate of 126 over a period of 21 days.

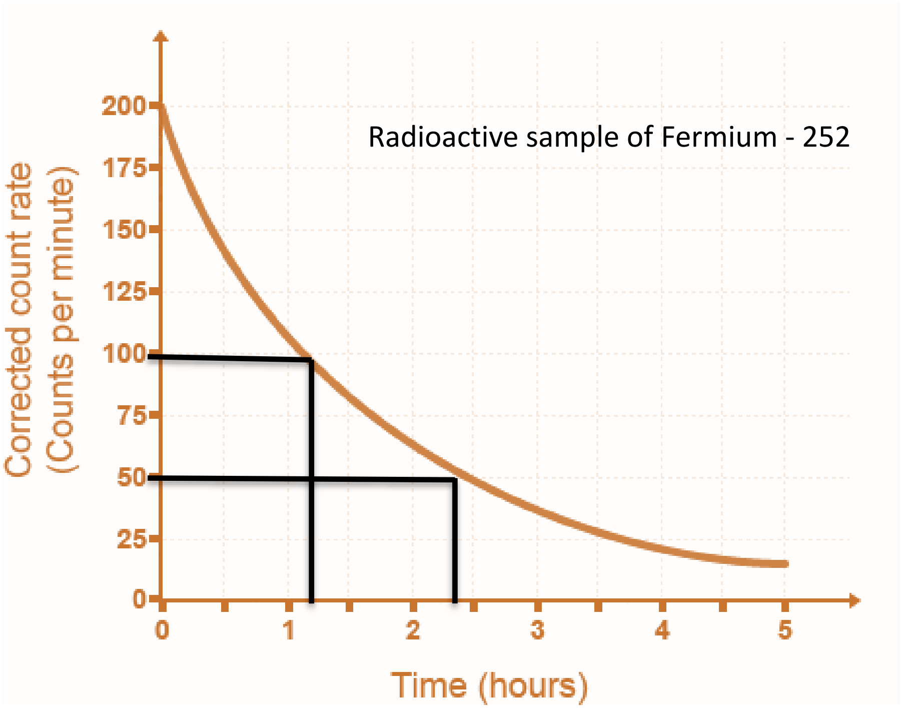
1008 → 504 → 252 → 126

1 2 3

3 half lives for count rate to fall to 126.

These 3 half lives took 21 days so each half life took 7 days.

Half life if this isotope = 7 days



200 counts / min at the beginning.

100 counts/min occurred after 1.2 hours.

50 counts/min occurred after 2.4 hours.

It always takes 1.2 hours for the count rate to halve.

Half life of Fermium - 252 = 1.2 hours.

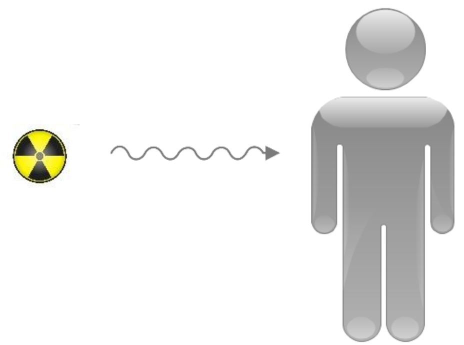
Radioactive materials are **hazardous** to **life**. **Nuclear radiation** can **ionise** (add or remove electrons) substances **within** the human body. This can **change** the way cells behave, **damage** DNA or **destroy** human cells.

Body part	Effect of ionising radiation
Hair	Hair loss
Skin	Can cause burns or lead to skin cancers
Reproductive organs	High doses can cause sterility or mutations in offspring
Thyroid	Exposure to radioactive iodine can destroy the cells in the thyroid or cause cancers
Bone marrow	Can cause leukaemia or other blood cancers

Rapidly dividing cells like cells that produce hair or those in the reproductive organs are most **susceptible** to **ionising radiation.**

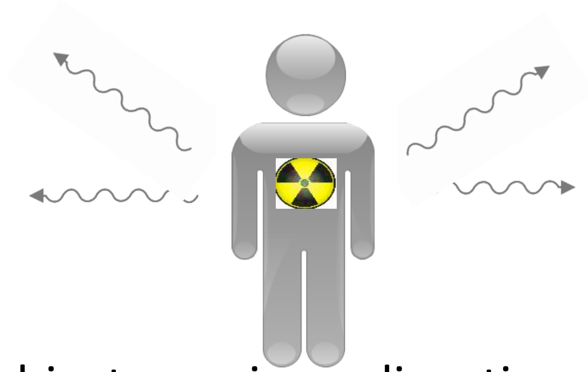
Radioactive irradiation and contamination

Irradiation is when an object or person is **exposed** to radiation. Protection from irradiation means stopping the radiation from reaching you.



Medical dressings are often irradiated but present no danger to the user.

Contamination is when a radioactive source is in **contact** with an object or person. The radioactive substance rather than the emissions are present.



The object remains radioactive until the contamination is removed or decays naturally.

Radioactive materials are hazardous, so certain **precautions** can be taken to reduce the risk when using radioactive sources. These include:

- wear **protective clothing** to prevent the body becoming contaminated should radioactive isotopes leak out
- limit the **dose** and monitor **exposure** using detector badges, etc

PiXL
partners in excellence

QuestionIT!

Part 2

- Radioactive decay and half life
- Uses and dangers of radioactivity

Part 2 – QuestionIT

1. Complete the nuclear equation for the beta decay of carbon

$$^{14}C \longrightarrow {}^{14}_{7}N \; +$$

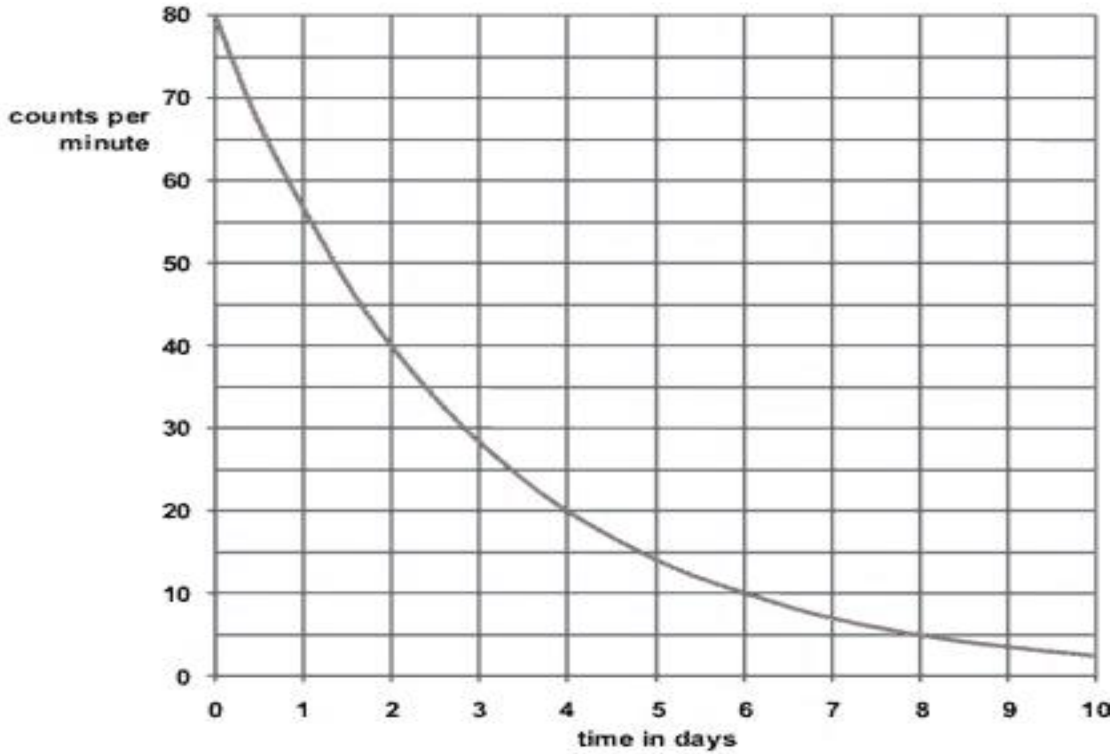
2. Uranium-235 undergoes an alpha decay to produce thorium-231. (atomic number of Uranium is 92). Complete the nuclear equation for this process.

3. When iodine 131 decays, there is no mass change in the nucleus and no new products formed. What type of radioactive emission is this?

4. Explain what is meant by the term "half life".

5. A radioactive sample reduces its count rate from 240 counts/min to 30 counts/min over a period of 60 hours what is its half life?

6. Use the decay curve below to work out the half-life of the isotope.



7. Calculate the net decline of the above isotope expressed as a ratio, during radioactive emission after 3 half-lives.

Part 2 – QuestionIT

8. Explain the difference between radioactive irradiation and radioactive contamination.

9. Copy and complete the table below to suggest one way of preventing exposure to irradiation and contamination by radioactive materials.

Type of exposure	Method of preventing exposure
Irradiation	
Contamination	

AnswerIT!

Part 2

- Radioactive decay and half life
- Uses and dangers of radioactivity

Part 2 – AnswerIT

1. Complete the nuclear equation for the beta decay of carbon

$$^{14}_{6}C \longrightarrow \, ^{14}_{7}N + \, ^{0}_{-1}e$$

2. Uranium-235 undergoes an alpha decay to produce thorium-231. (atomic number of Uranium is 92). Complete the nuclear equation for this process.

$$^{235}_{92}U \longrightarrow \, ^{231}_{90}Th + \, ^{4}_{2}\alpha$$

3. When iodine 131 decays, there is no mass change in the nucleus and no new products formed. What type of radioactive emission is this?

   Gamma emission

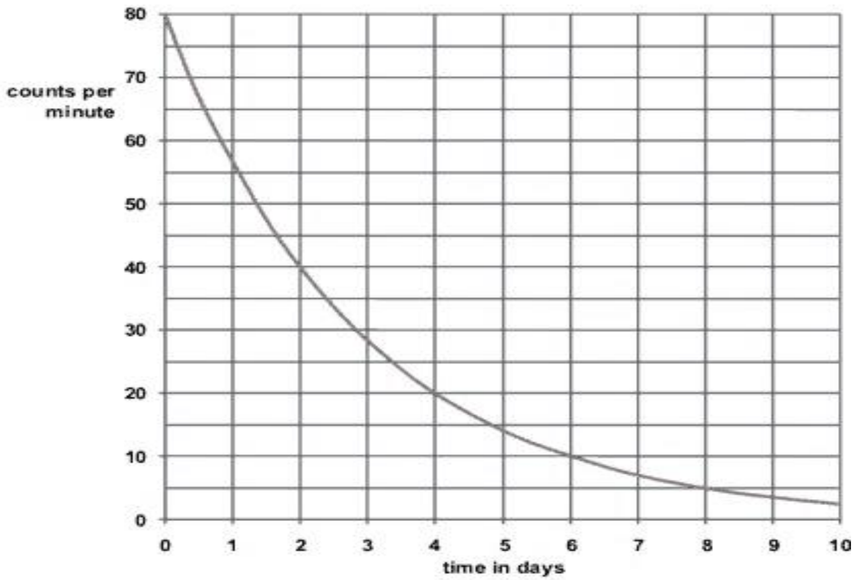
4. Explain what is meant by the term "half life". **The time it takes a radioactive sample to lose half its radioactivity (as measured by count rate).**

5. A radioactive sample reduces its count rate from 240 counts/min to 30 counts/min over a period of 60 hours what is its half life?

240 → (1) → 120 → (2) → 60 → (3) → 30

Three half lives in 60 hours = 20 hour half life

6. Use the decay curve below to work out the half-life of the isotope.



80 = 0 day; 40 = 2 days. Difference = 2 days. Half-life = 2 days

7. Calculate the net decline of the above isotope expressed as a ratio, during radioactive emission after 3 half-lives.

Counts/ min reduce from 80 to 10 in 3 half-lives.
Decline is 70/80 or 7/8ths

8. Explain the difference between radioactive irradiation and radioactive contamination.
   Irradiation is exposure to emissions from radioactive materials that are not in contact with an object. Contamination is when radioactive materials are in contact with the object.
9. Copy and complete the table below to suggest one way of preventing exposure to irradiation and contamination by radioactive materials.

Type of exposure	Method of preventing exposure
Irradiation	Wear protective clothing, e.g., lead apron, to shield from radiation. Move away from the radiation. Shield the radiation with appropriate material.
Contamination	Avoid contact with radioactive materials. Prevent radioactive materials being released into the environment.