Edexcel GCSE Physics

Your notes

Uses & Dangers of Radiation

Contents


Your notes

Dangers of Radiation

- Ionising radiation can damage human cells and tissues
- This could be in terms of:
  - Tissue damage
  - Mutations

Tissue Damage

- Radiation is effectively used to destroy cancerous tumour cells
- However, it can cause damage to healthy tissue if it is not properly targeted
- This is mostly from high-energy radiation such as gamma rays and X-rays

Mutations

- If the atoms that make up a DNA strand are ionised then the DNA strand can be damaged
- If the DNA is damaged then the cell may die, or the DNA may be **mutated** when it reforms
- If a mutated cell is able to replicate itself then a **tumour** may form
  - This is an example of **cancer**, which is a significant danger of radiation exposure

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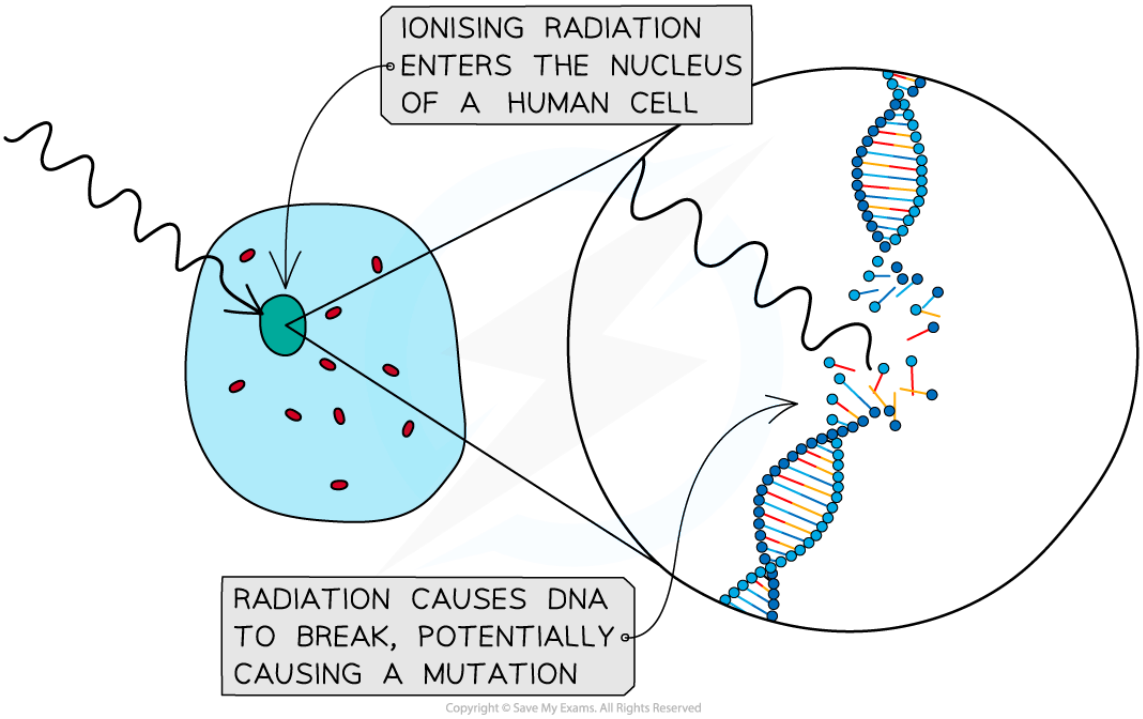


Diagram showing the damage caused to DNA by ionising radiation. Sometimes the cell is able to successfully repair the DNA, but incorrect repairs can cause a mutation

- Acute radiation exposure can have other serious symptoms:
  - It can cause skin **burns**, similar to severe sunburn
  - Radiation can **reduce** the amount of **white blood cells** in the body, making a person more susceptible to infections by lowering their immune system
- Because of this, it is very important to handle radioactive sources carefully

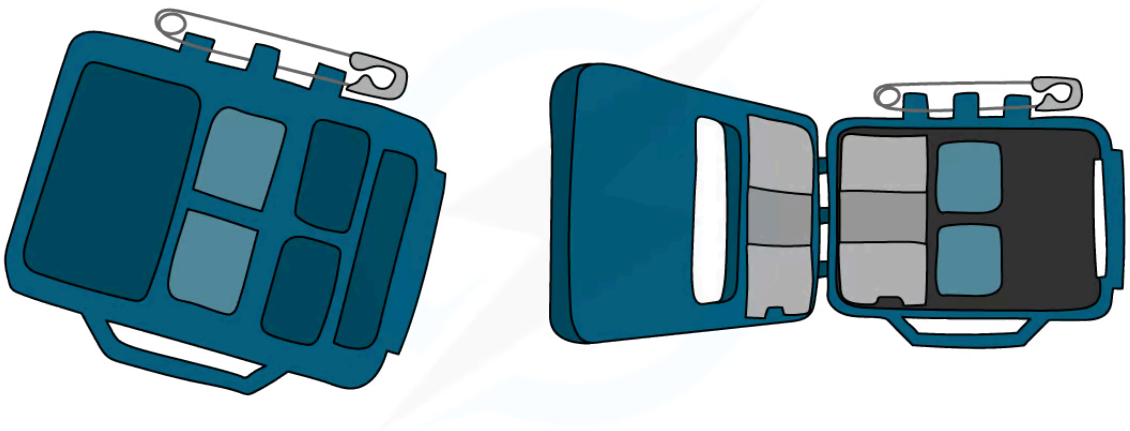
Handling Radiation Safely

- To mitigate the risks of radiation exposure, there are some safe practices that should be used:
  - Radioactive sources should be kept in a **shielded container** when not in use, for example, a lead-lined box
  - Radioactive materials should only be handled when wearing **gloves**, and with **tongs** to increase the distance from them
  - It may be appropriate to wear **protective clothing** to prevent the body becoming contaminated

- The **time** that a radioactive source is being used for should be **limited**

Regulating Exposure

- Because of the harmful effects of radiation, it is important to **regulate** the exposure of humans to radiation
- The amount of radiation received by a person is called the dose and is measured in **sieverts** (Sv)
- One sievert is a very big dose of radiation
  - It would cause acute **radiation poisoning**
- People would normally receive about 3 mSv (0.003 Sv) in one year
- To protect against over-exposure, the dose received by different activities is measured
- A dosemeter measures the amount of radiation in particular areas and is often worn my radiographers, or anyone working with radiation



A dosemeter, or radiation badge, can be worn by a person working with radiation in order to keep track of the amount of radiation they are receiving

Differences in Exposure

- The amount of radiation that a person receives is affected by a person's **occupation, lifestyle** or **location**
- Some areas around the world have higher **background radiation** because they are closer to sources of radiation

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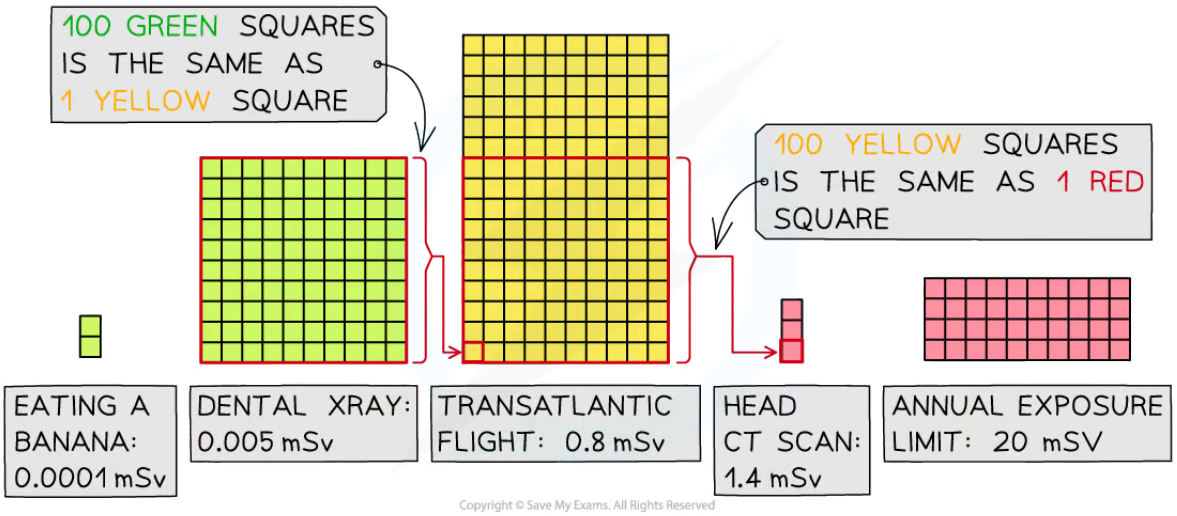
- People that work with nuclear radiation receive more radiation
  - The UK limit for nuclear industry employees is 20 mSv in one year
- The diagram below compares the dose received by some different activities



All living things emit a small amount of radiation: the amount of radiation within a banana is tiny, and not at all dangerous!

Worked Example

A student plans to use a gamma source to conduct an experiment. List four things that the student should do in order to minimise the risk to themselves when using the source.

Answer:

Any four from:

- Keep the source in a lead lined container until the time it is needed
- Use tongs to move the source, rather than handling it directly
- The source should be kept at as far a distance from the student as possible during the experiment
- The time that the source is being used should be minimised
- After the experiment the student should wash their hands
- The date and the time that the radiation has been used for should be recorded

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Contamination & Irradiation

Contamination

- Contamination is defined as:

  The unwanted presence of materials containing radioactive atoms on other materials

- A substance is only radioactive if it contains radioactive atoms that emit radiation
- Contamination occurs when a radioactive isotope gets onto a material where it should not be
  - This is often due to a radiation leak
- As a result of this, the small amounts of the isotope in the contaminated areas will emit radiation and the material becomes radioactive

The Assassination of Alexander Litvinenko

- Contamination is almost always a mistake or an accident
  - However, in 2006 a former Russian spy was poisoned by a radioactive isotope
- His name was Alexander Litvinenko and he was contaminated with the isotope **polonium-210**
  - He died because of the poisoning

It is believed that the polonium-210 that poisoned Alexander Litvinenko was secretly put into a cup of tea he was drinking

Irradiation

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- Irradiation is defined as:

  The process of exposing a material to alpha, beta or gamma radiation

- Irradiating a material **does not** make that material radioactive
  - However, it **can** kill living cells

This sign is the international symbol indicating the presence of a radioactive material

- Irradiation can be used as a method of **sterilisation**:
  - Surgical equipment is irradiated before being used in order to kill any micro-organisms on it before surgery
  - Food can be irradiated to kill any micro-organisms within it
  - This makes the food last longer without going mouldy

Hazards of Irradiation and Contamination


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- Although irradiation can cause harm, contamination has the potential to cause far more harm, due to the continuous exposure to radiation that it will produce
- **Contamination** is particularly dangerous if a radioactive source gets into the human body
  - The internal organs will be irradiated as the source emits radiation as it moves through the body

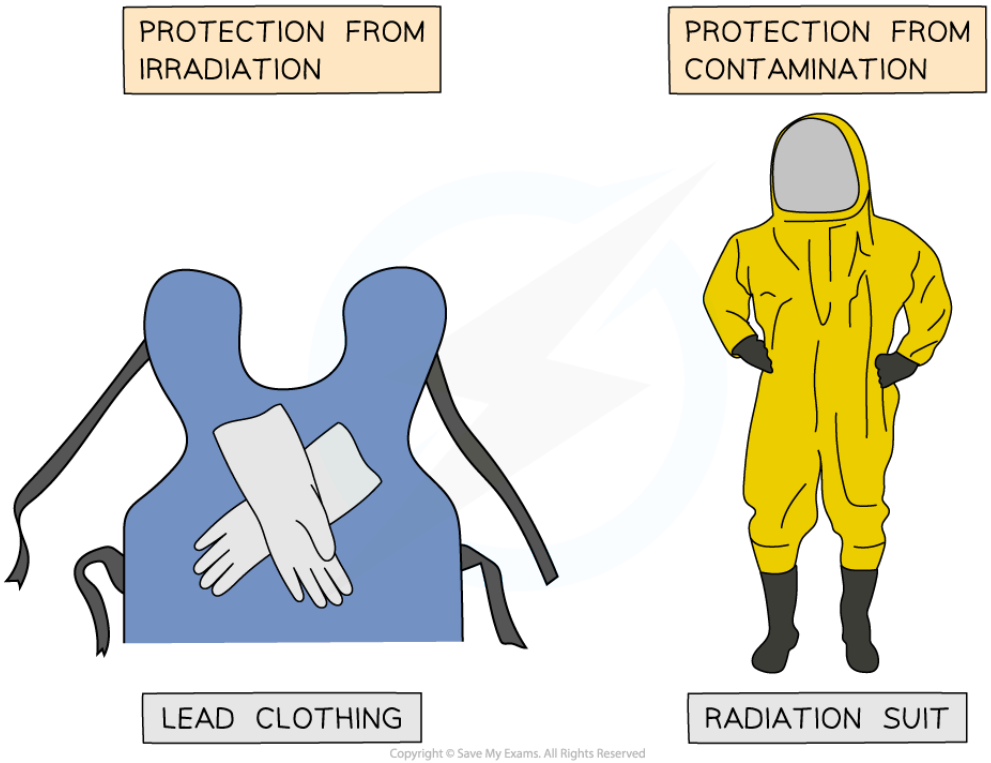
Comparison of Irradiation and Contamination Table

	Irradiation	Contamination
Description	Object is exposed to radiation but does not become radioactive	Object becomes radioactive and emits radiation
Source	Danger is from radiation emitted outside the object	Danger from radiation emitted within the object
Prevention	Prevented by using shielding, such as lead clothing	Prevented by safe handling of sources and airtight safety clothing
Causes	Caused by the presence of radioactive sources outside the body	Caused by inhalation or ingestion of radioactive sources

Protecting against Irradiation and Contamination

- It is important to reduce the risk of exposure to radiation
- Radiation can mutate DNA in cells and cause cancer
- **Shielding** is used to absorb radiation
  - Lead lined suits are used to reduce irradiation for people working with radioactive materials
  - The lead absorbs most of the radiation that would otherwise hit the person

- To prevent contamination an airtight suit is used by people working in an area where there may have been a radiation leak
  - This prevents radioactive atoms from getting inside the person



Lead shielding is used when a person is getting an x-ray, as well as for people who work with radiation. Contamination carries much greater risks than irradiation

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Worked Example

Summarise the difference in the risk posed by radioactive sources with very short and very long half-lives with regards to:

(a) Irradiation.

(b) Contamination.

Answer:

Part (a)

Sources with short half-lives present a greater risk of irradiation

- A short half-life means a source has a **high activity**
- This means there is a high rate of radioactive emissions, compared to a source with a long half-life

Part (b)

Sources with long half-lives present a greater risk of contamination

- Sources with long half-lives will **remain radioactive for longer**
- They need to be controlled for longer, to prevent them spreading
- Shielding and storage may be required

Examiner Tips and Tricks

Irradiation and contamination are very commonly confused. Remember that something is radioactive **only** if it contains radioactive atoms. This can only occur from contamination, **not** from irradiation!

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Uses of Radiation

- Radiation is used in a number of different ways:
  - Medical procedures including diagnosis and treatment of cancer
  - Sterilising food (irradiating food)
  - Sterilising medical equipment
  - Determining the age of ancient artefacts
  - Checking the thickness of materials
  - Smoke detectors (alarms)
- The properties of the different types of radiation determine which one is used in a particular application

Smoke Detectors

- Alpha particles are used in smoke detectors
- The alpha radiation will normally **ionise** the air within the detector, creating a current
- The alpha emitter is blocked when smoke enters the detector
- The alarm is triggered by a microchip when the sensor no longer detects alpha

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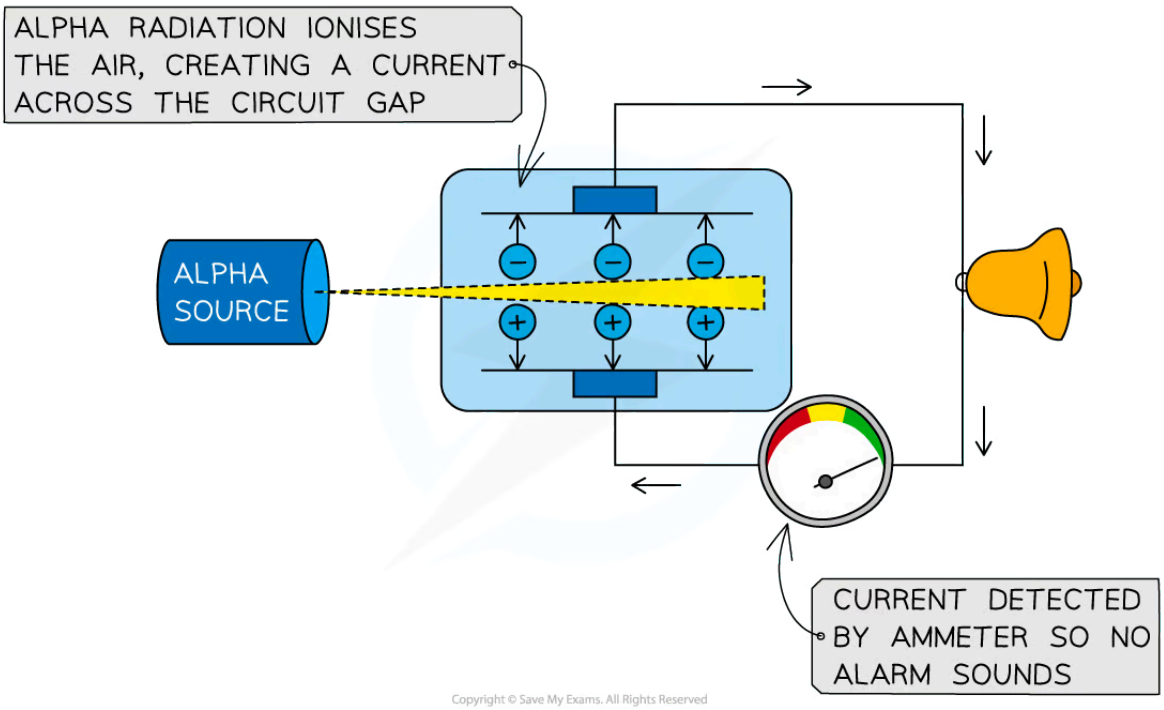

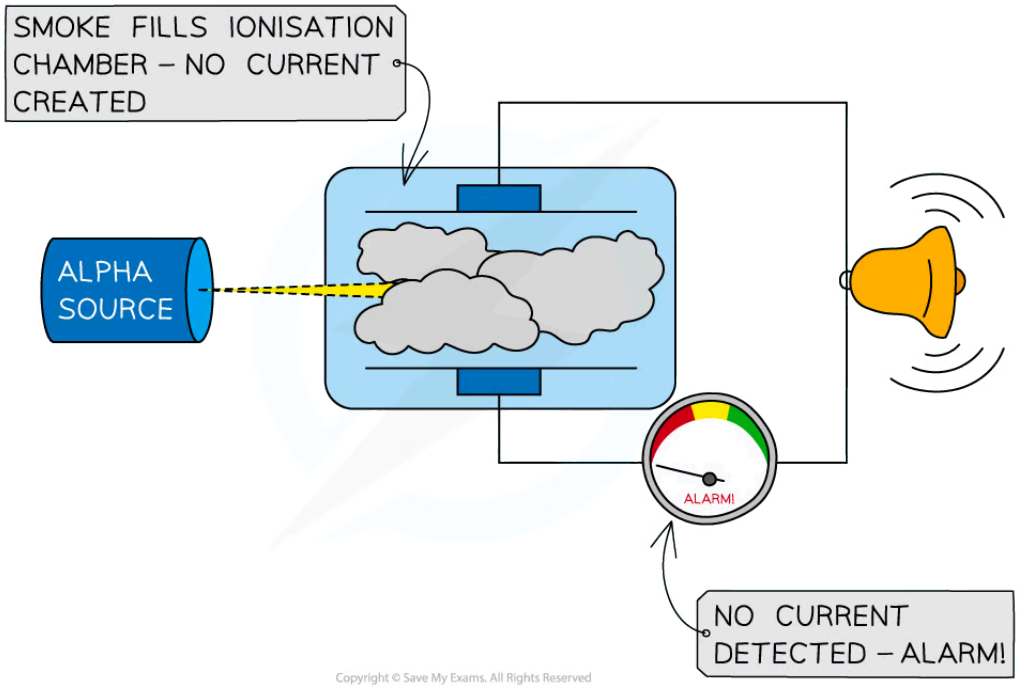

In the diagram on the right, alpha particles are stopped by the smoke, preventing the flow of current and triggering the alarm

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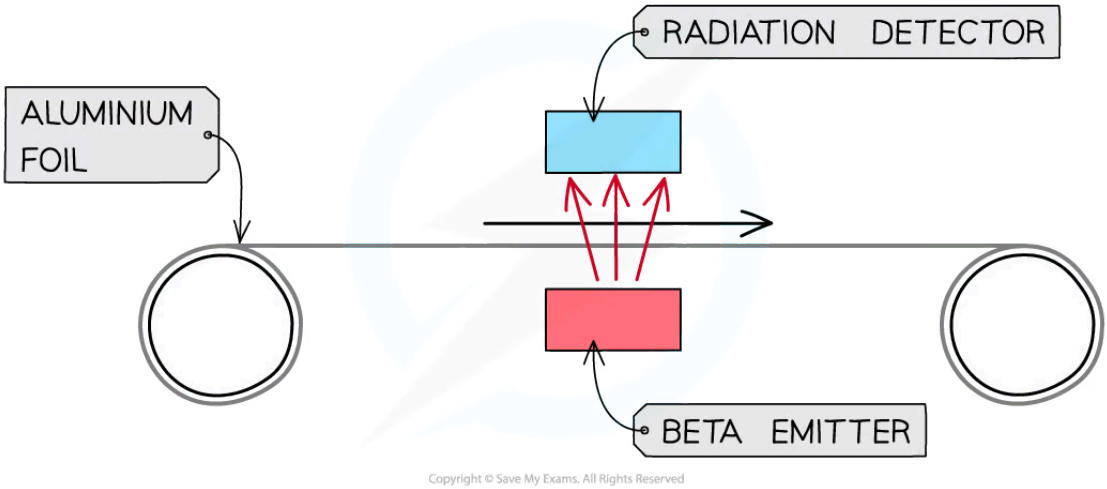
Measuring the Thickness of Materials

- Radiation can be used for tracing and gauging thickness
  - Mostly commonly this is **beta** particles
- As a material moves above a **beta** source, the particles that are able to penetrate it can be monitored using a detector
- If the material gets **thicker, more** particles will be absorbed, meaning that **less** will get through
  - If the material gets **thinner** the **opposite** happens
- This allows the machine to make **adjustments** to keep the thickness of the material **constant**



Beta particles can be used to measure the thickness of thin materials such as paper, cardboard or aluminium foil

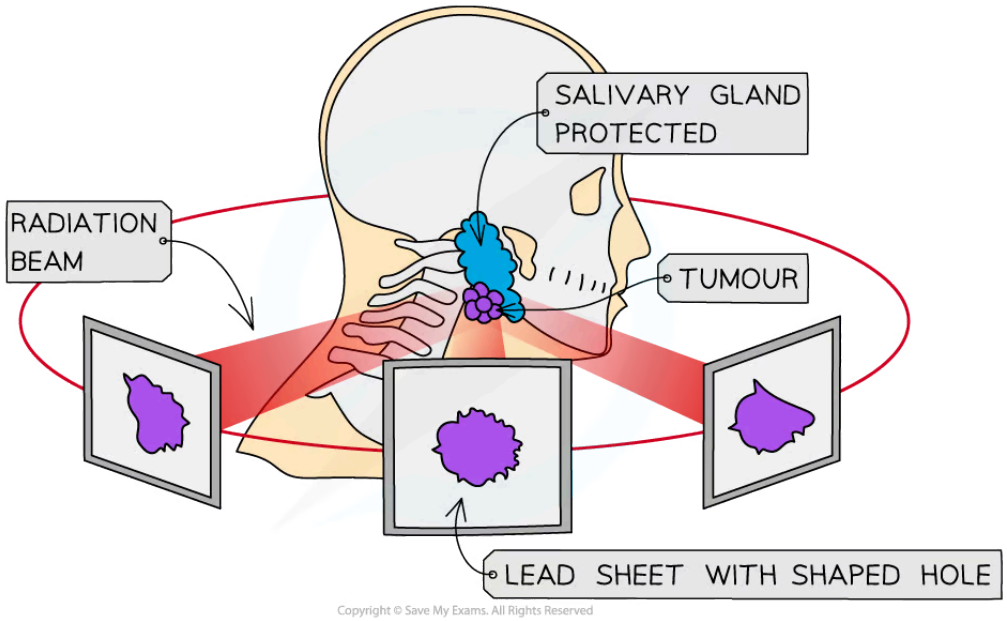
- Beta radiation is used because it will be **partially absorbed** by the material
  - If **alpha** particles were used **all of them would be absorbed** and none would get through
  - If **gamma** were used almost **all of it would get through** and the detector would not be able to sense any difference if the thickness were to change

Diagnosis and Treatment of Cancer

- **Radiotherapy** is the name given to the treatment of cancer using radiation

(Chemotherapy is treatment using chemicals)

- Although radiation can cause cancer, it is also highly effective at **treating** it
- Radiation can kill living cells. Some cells, such as bacteria and cancer cells, are more susceptible to radiation than others
- Beams of gamma rays are directed at the cancerous tumour
  - Gamma rays are used because they are **able to penetrate the body**, reaching the tumour
  - The beams are moved around to minimise harm to healthy tissue whilst still being aimed at the tumour
- A **tracer** is a radioactive isotope that can be used to track the movement of substances, like blood, around the body
  - A PET scan can detect the emissions from a tracer to diagnose cancer and determine the location of a tumour



Radiation therapy to remove a tumour

Sterilising Food and Medical Equipment

- Gamma radiation is widely used to **sterilise** medical equipment
- Gamma is most suited to this because:
  - It is the most **penetrating** out of all the types of radiation

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- It is penetrating enough to irradiate **all sides** of the instruments
- Instruments can be sterilised without removing the **packaging**

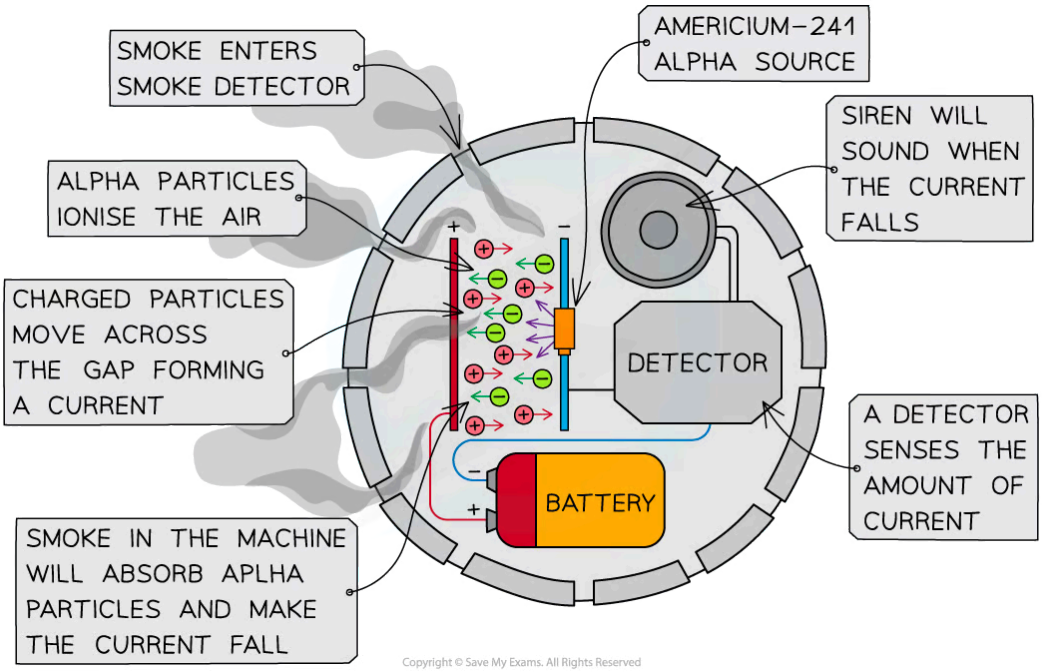
- Food can be irradiated in order to **kill any microorganisms** that are present on it
- This makes the food last longer, and reduces the risk of food-borne infections

Food that has been irradiated carries this symbol, called the Radura. Different countries allow different foods to be irradiated

Worked Example

Use the diagram to explain why is alpha radiation used in smoke detectors, and not beta or gamma radiation.

Your notes



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Answer:

- Consider the different properties of alpha, beta and gamma:
  - **Alpha** is the most **weakly** penetrating and **strongest** ioniser
  - **Beta** and **gamma** have **stronger** penetrating power and **weaker** ionising power
- If beta or gamma radiation were used in this situation then they would pass straight through the smoke and the alarm would not go off
- Therefore, since alpha is **absorbed** by smoke, and beta and gamma are not, this makes it **most suitable** for use in a smoke detector

Examiner Tips and Tricks

If you are presented with an unfamiliar situation in your exam don't panic! Just apply your understanding of the properties of alpha, beta and gamma radiation. Mainly think about the range (how far it can travel) and ionising power of the radiation to help understand which radiation is used in which situation.

Half-Life & Risk

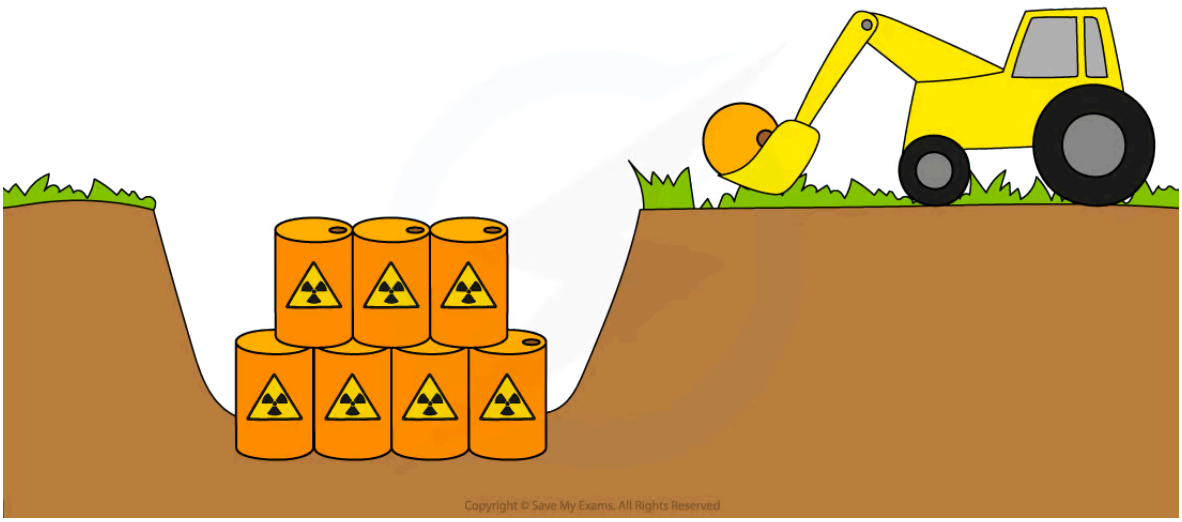
- The half-life is the time it takes for the activity of a radioactive source to decrease to half of its original value
- Different radioactive isotopes can have **very different half-lives**
- For example:
  - Francium-218 has a half-life of only 1 millisecond (0.001 seconds)
  - Polonium-210 has a half-life of about 140 days
  - Uranium-235 has a half-life of about 700 million years

Short Half-Life Values

- If an isotope has a short half-life, the nuclei **will decay very quickly**
  - This means that the isotope will emit a lot of radiation in a short amount of time
- If only a small amount of the isotope is used, having a short half-life can be advantageous, as the material will quickly lose its radioactivity
- If a large amount is used, however, the levels of radiation emitted could make handling the isotope **extremely dangerous**

Long Half-Life Values

- If an isotope has a long half-life then a sample of it will decay slowly
  - Although it may not emit a lot of radiation, it will **remain radioactive for a very long time**
- Sources with long half-life values present a risk of contamination for a much longer time
- Radioactive waste with a long half-life is buried underground to prevent it from being released into the environment



Depending on the activity of radioactive waste, it is buried in different ways

Your notes

Worked Example

Summarise the difference in the risk posed by radioactive sources with very short and very long half-lives with regards to:

(a) Irradiation.

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Answer:

Part (a)

- A short half-life means a source has a **high activity**
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Part (b)

- Sources with long half-lives will **remain radioactive for longer**
- They need to be controlled for longer, to prevent them spreading
- Shielding and storage may be required

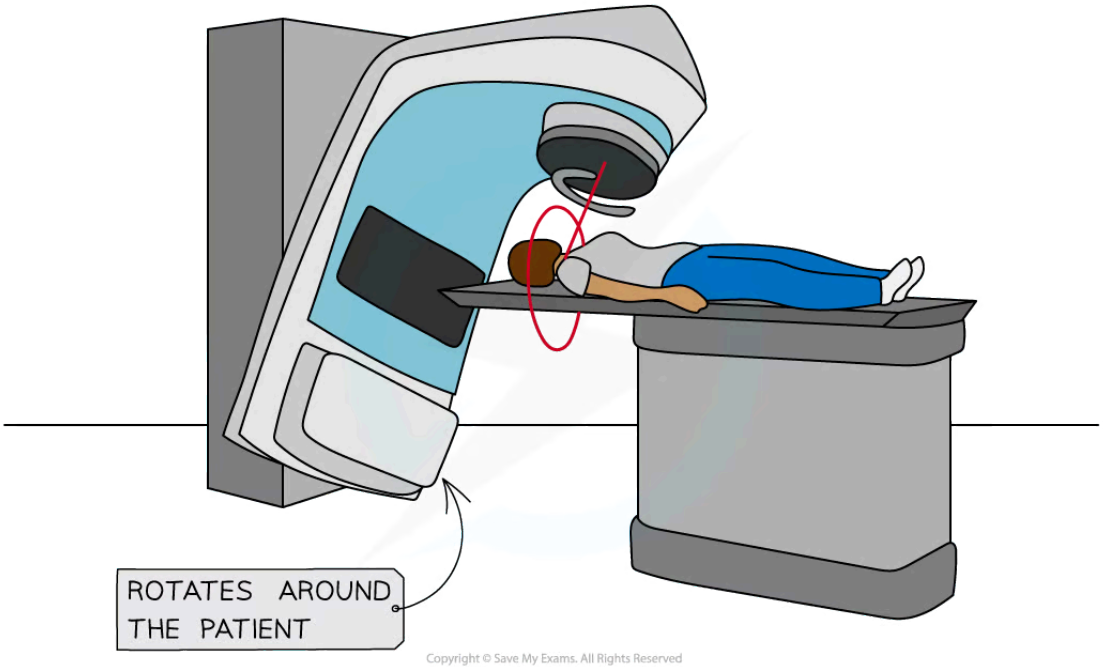
Medical Uses of Radiation

Your notes

Radiotherapy

Radiotherapy

- Radiotherapy is the name given to the treatment of cancer using radiation
- Although radiation can **cause** cancer, it is also highly effective at **treating** it
- Radiation can **kill** living cells
  - Some cells, such as bacteria and cancer cells, are more susceptible to radiation than others
- During external radiotherapy, beams of gamma rays are **directed** at the cancerous tumour
  - Surrounding healthy tissue tends to be shielded to avoid causing any damage



During radiotherapy, the beams are moved around to minimise harm to healthy tissue whilst still being aimed at the tumour

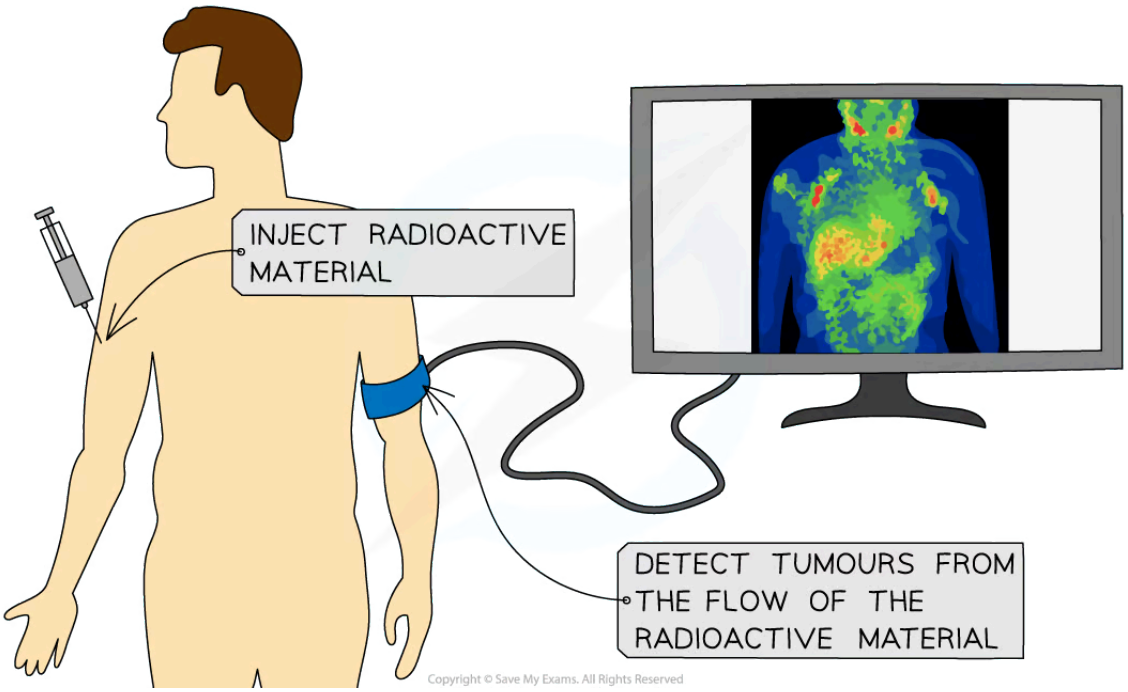
- During internal radiotherapy, small pellets of radioactive materials can also be inserted into a tumour exposing it directly to radiation

PET Scanners and Tracers

Your notes

Medical Tracers

- A **tracer** is a radioactive isotope that can be used to track the movement of substances, like blood, around the body
- Gamma emitters are usually used for this purpose
  - Gamma rays are highly penetrating and so will be able to pass through the body and be detected **outside** the body
- This allows an internal image of the body to be created



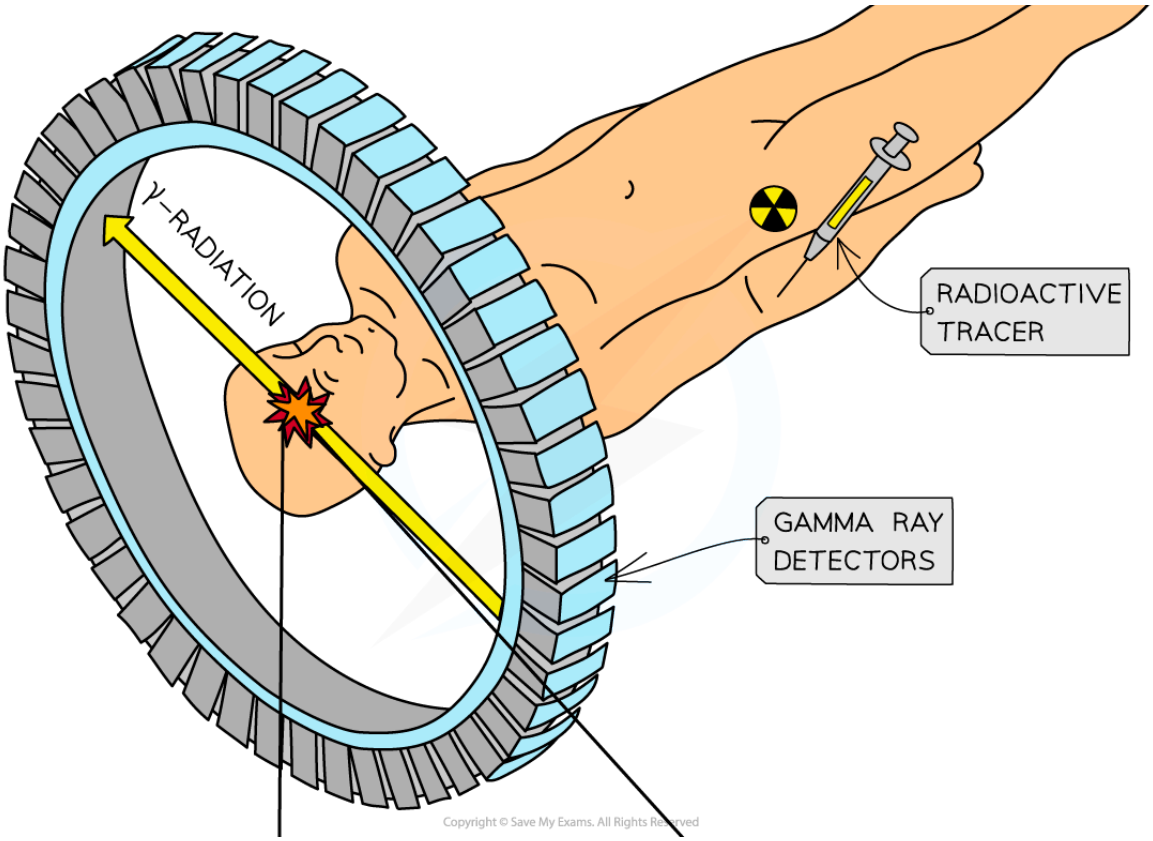
Iodine-131 is an example of a radioactive tracer

- Since gamma rays are less ionising than some other forms of radiation, the harm caused to the patient is also minimised
- As well as choosing a gamma emitter:
  - The amount of isotope used is kept to a minimum to reduce people's exposure to radiation
  - Isotopes are chosen that have **short half-lives** of around a few hours: Long enough to carry out the procedure, but not so long that they cause long term harm

Positron Emission Tomography (PET)

Your notes

- In PET scanning positrons are emitted by the decay of the tracer
- They travel a small distance and annihilate when they interact with electrons in the tissue
- This produces a pair of gamma-rays (also called gamma (γ) photons) which can be detected outside the body



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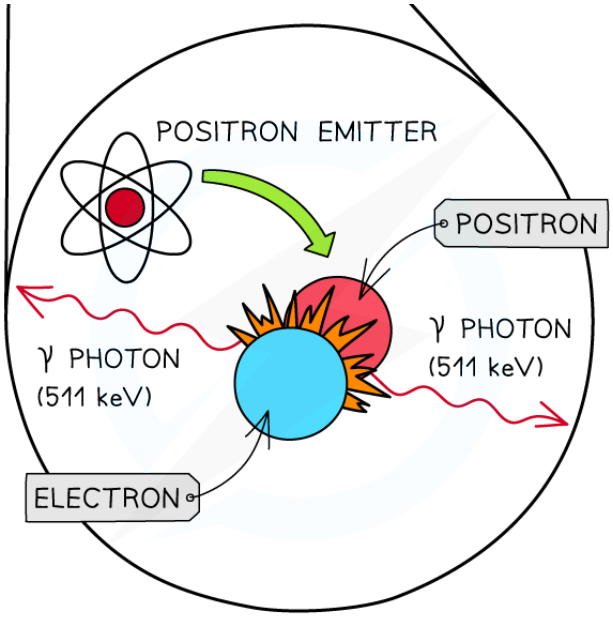

The photons (produced by the annihilation of the electron and positron) are detected outside the body. keV are a unit of energy.

Worked Example

A new medical tracer is required for investigating the absorption of a particular substance found in blood around the body.

Isotope	Type of Radiation Emitted	Half-life
A	Alpha	8 hours
B	Gamma	10 seconds
C	Gamma	2 days
D	Beta	4 years

Which of the different isotopes in the table would be most suitable?

Answer: C

A suitable medical tracer must:

- Be able to penetrate out of the body
- Have a long enough half-life to move around the body before it decays away
- Have a short enough half-life that it won't remain in the body at dangerous levels for too long
- The answer is **not A** because alpha radiation cannot penetrate out of the body
- The answer is **not B** because the half-life is too short
- The answer is **not D** because the half-life is too long

Your notes

Isotope Production

- When carrying out procedures involving the use of radioactive isotopes, such as the PET scan, the amount used is kept to a minimum to reduce people's exposure to radiation
- Isotopes are chosen that have **short half-lives** of around a few hours: Long enough to carry out the procedure, but not so long that they cause long term harm
- Because of the short half-life of the isotopes involved, the **isotopes have to be produced nearby** – otherwise they would have decayed too much by the time they reached the hospital and be unusable

Examiner Tips and Tricks

The use of radiation in medicine carries **risk.** However, the benefits of using radiation in medicine can out way the potential risks: the risks posed by the radiation are smaller than the risks associated with leaving the condition untreated. You may be given data and asked to evaluate the risk of nuclear radiation in a particular example. Remember to **compare** the potential dangers with the benefits.