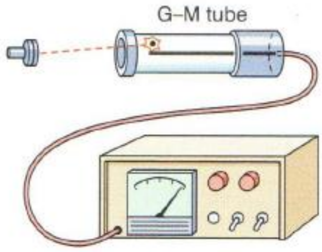
Radioactivity

DETECTION OF RADIOACTIVITY

All ionising radiation is invisible to the naked eye but it affects photographic plates. Individual particles of ionising radiation (α-particles, β-particles and γ-rays) can be detected using a Geiger–Müller tube as shown in Fig. 5.5. You can distinguish between the types of radiation using their properties (see Fig. 5.7 and Table 5.2).



Δ Fig. 5.5 Radioactivity is measured using a Geiger–Müller tube linked to a counter.

There is *always* ionising radiation present. This is called **background radiation**. Background radiation comes from both natural and manmade sources. Background radiation is caused by radioactivity in soil, rocks and materials like concrete; radioactive gases in the atmosphere; and cosmic rays, which come from somewhere in outer space, though we are still not sure *exactly* where.

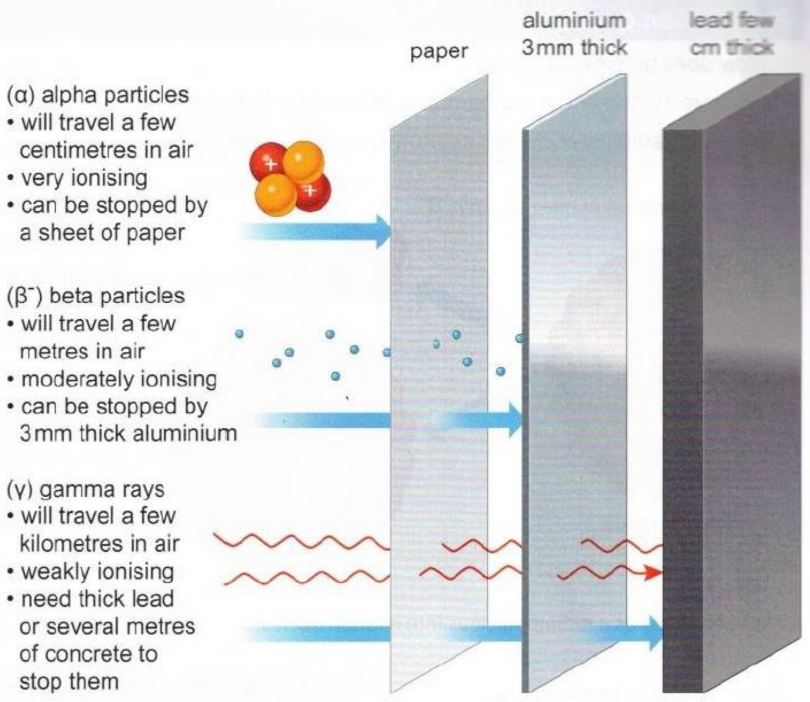
Δ Fig. 5.6 GM tube.

Ionising and penetrating radiation

The types of radiation described above are all examples of ionising radiation, and they can all **penetrate** (pass through) materials.

Alpha particles are emitted at high speeds. Due to this and their high relative mass, they transfer a lot of energy and so are good at ionising atoms they encounter. However, each time they ionise an atom they lose energy. Since they produce many ions in a short distance, they lose energy quickly and have a short penetration distance.

Beta particles are much less ionising than alpha particles and so can penetrate much further into matter than alpha particles can. Gamma-rays are about ten times less ionising than beta particles and can penetrate matter easily.



C the penetrating properties of alpha, beta and gamma radiation

Dangers of Radioactivity

A This patient has radiation burns. He was among the first emergency personnel on the scene after the Chernobyl nuclear power plant disaster on 26 April 1986.

A large amount of ionising radiation can cause tissue damage such as reddened skin (radiation burns) and also other effects that cannot be seen.

Small amounts of ionising radiation over long periods of time can damage the DNA inside a cell. This damage is called a **mutation**. DNA contains the instructions controlling a cell, so some mutations can cause the cell to malfunction and may cause cancer. Gene mutations that occur in gametes can be passed on to the next generation. However, not all mutations are harmful and cells are often capable of repairing the damage if the radiation **dose** is low.

8th **1** Describe two effects of ionising radiation on the human body.

Radiation is a hazard, because it can cause harm. We are exposed to background radiation all the time, but we are only exposed to small amounts so the risk of harm is low. However, people who work with radioactive materials could be exposed to more radiation and so must take precautions to minimise the risks from radiation.

Handling radioactive sources

The intensity of radiation decreases with distance from the source, so sources are always handled with tongs. The risk can also be reduced by not

B Radioactive sources are handled with tongs.

pointing sources at people and storing them in lead-lined containers.

2 Explain why radioactive sources are handled with tongs and stored in lead-lined containers.

Radiation in hospital

Medical staff working with radioactive sources have their exposure limited in a number of ways, including increasing their distance from the source, shielding the source and minimising the time they spend in the presence of sources. Their exposure is also closely monitored using dosimeter badges (see *SP6d Background radiation*).

Some patients may be exposed to a dose of radiation for medical diagnosis or treatment (such as detecting and treating cancer). This is only done when the benefits are greater than the possible harm the radiation could cause, and the minimum possible dose is used, and sources with short half-lives are used to minimise the time for which the patient is exposed.

Nuclear accidents

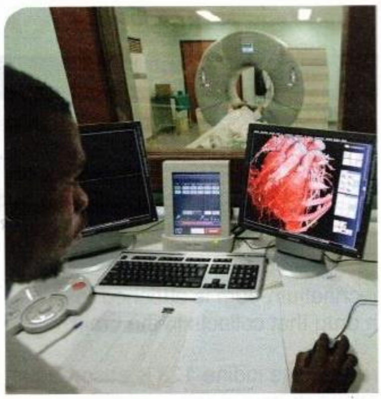
Occasionally there is an accident in a nuclear power station, allowing radioactive materials to escape into the environment. Accidents such as this cause a hazard, as they may lead to people being irradiated or contaminated.

Someone is irradiated when they are exposed to alpha, beta or gamma radiation from nearby radioactive materials. Once the person moves away the irradiation stops.

Someone becomes **contaminated** if they get particles of radioactive material on their skin or inside their body. They will be exposed to radiation as the unstable isotopes in the material decay, and this will continue until the material has all decayed or until the source of contamination is removed (which is not always possible). Water and soils can also be contaminated, so contamination can spread into the food chain. Contamination with radioactive materials with long half-lives poses a greater hazard as the effects will last longer than for materials with shorter half-lives.

D These workers are cleaning up after an accident at a nuclear reactor. The overalls stop their clothing becoming contaminated.

It is important to understand that the dangers of radiation from medicine, industry and power generation are small compared with many other aspects of our modern lives. However, many people are concerned that accidents may happen in nuclear power stations.



C behind a radiation shield in a hospital

Did you know?

When radioactivity was first discovered, people did not know of the harm it could cause. Radioactive substances such as thorium and radium were put into face creams and other products because people thought they might have health benefits.

Checkpoint

How confidently can you answer the Progression questions?

Strengthen

S1 What are the hazards posed by radiation?

SAFETY PRECAUTIONS

Alpha, beta and gamma radiation can all damage living cells. Alpha particles, due to their strong ability to ionise other particles, are particularly dangerous to human tissue. However, they cannot penetrate skin, so when alpha sources are outside the body they are relatively harmless. If they are swallowed, inhaled, etc. they cause a lot of cell damage. Gamma radiation is dangerous because of its high penetrating power. However, the cell has repair mechanisms that make ordinary levels of gamma radiation relatively harmless.

Nevertheless, radiation can be very useful – it just needs to be used *safely*.

Safety precautions for handling radioactive materials include:

- Use forceps when moving radioactive sources – don't hold them directly.
- Do not point radioactive sources at living tissue.
- Store radioactive materials in lead-lined containers – and lock the containers away securely.
- Check the surrounding area for radiation levels above normal background levels.

High levels of radiation are extremely hazardous. People who deal with highly radioactive materials must wear special film badges (containing photographic film) that monitor the dose they receive. They may need to wear protective clothing, perhaps containing sheets of lead, and at the end of each shift they will need to check for radioactivity on their bodies and may need to shower.

Using Radioactivity

A All these strawberries are several days old. The ones on the left were irradiated with gamma rays.

Killing microorganisms

All foods contain microorganisms that eventually cause them to decompose. Some bacteria also cause food poisoning. Food can be **irradiated** with gamma rays to kill bacteria. This makes it safer to eat and also means that it can be stored for longer before going off. It does not make the food more radioactive, although some foods are naturally radioactive.

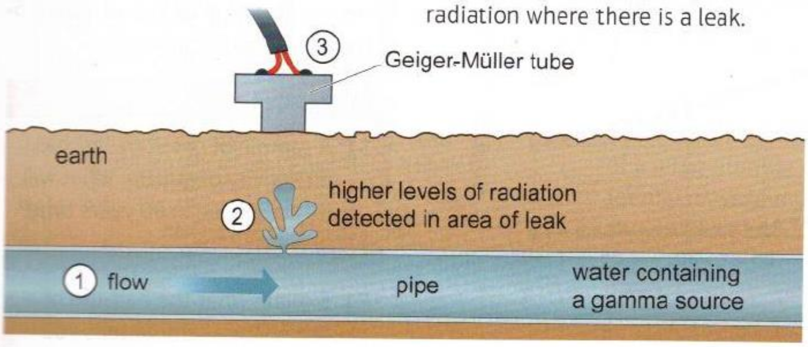
Surgical instruments need to be **sterilised** to kill microorganisms. The usual method is to heat them. Some instruments such as plastic syringes cannot be sterilised using heat, so they are sealed into bags and irradiated with gamma rays, which can penetrate the bags and the equipment.

7th **1** What happens when food is irradiated?

7th **2** Suggest why surgical equipment is sealed into bags before irradiation.

Radioactive detecting

Radioactive isotopes can be used as **tracers**. For example, a gamma source added to water is used to detect leaks in water pipes buried underground. Where there is a leak, water flows into the surrounding earth. A Geiger-Müller tube following the path of the pipe will detect higher levels of radiation where there is a leak.



B using a gamma source to detect a leak

Cancer

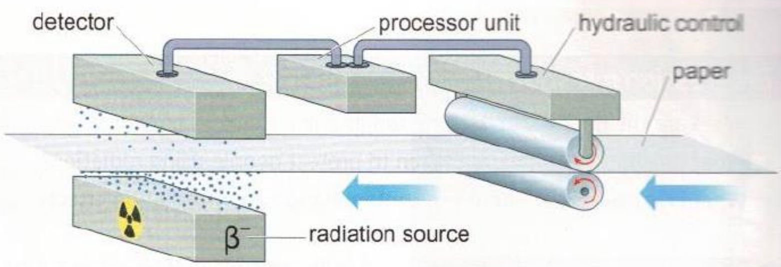
Radioactivity can be used to help diagnose cancer using tracers in the body. It can also be used to treat cancer. You will learn more about this in *SP6j Radioactivity in medicine*.

8th **3** Explain why gamma sources are used as tracers rather than beta sources.

Checking thickness

Paper is made by squeezing wood pulp between rollers. Paper can be made in different thicknesses and the rollers need to squeeze the wood pulp with a force that produces the correct thickness of paper. The detector in diagram C counts the rate at which beta particles get through the paper from a source on one side.

When the paper is too thin, more beta particles penetrate the paper and the detector records a higher count rate. A computer senses that the count rate has risen and reduces the force applied to the rollers to make the paper thicker. When the paper is too thick, the opposite happens.



C A beta particle detector is used to control the thickness of paper during its manufacture.

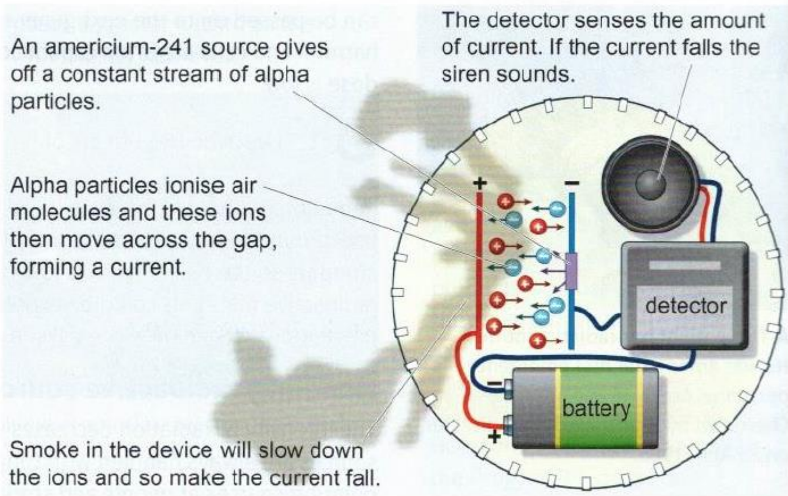
8th **4** Look at diagram C. Explain what happens when the paper is too thick.

7th **5** Why would you not use an alpha source to monitor paper thickness?

Smoke alarms

A smoke alarm contains a source of alpha particles, usually a radioactive isotope called americium-241. The detector has an electrical circuit with an air gap between two electrically charged plates. The americium-241 source releases alpha particles, which ionise molecules in the air. These ions are attracted to plates with an opposite charge and so allow a small electrical current to flow.

As long as this current is flowing, the alarm will not sound. When smoke gets into the air gap the smoke particles slow down the ions. This means that the current flowing across the gap decreases. The alarm sounds when the current drops below a certain level.

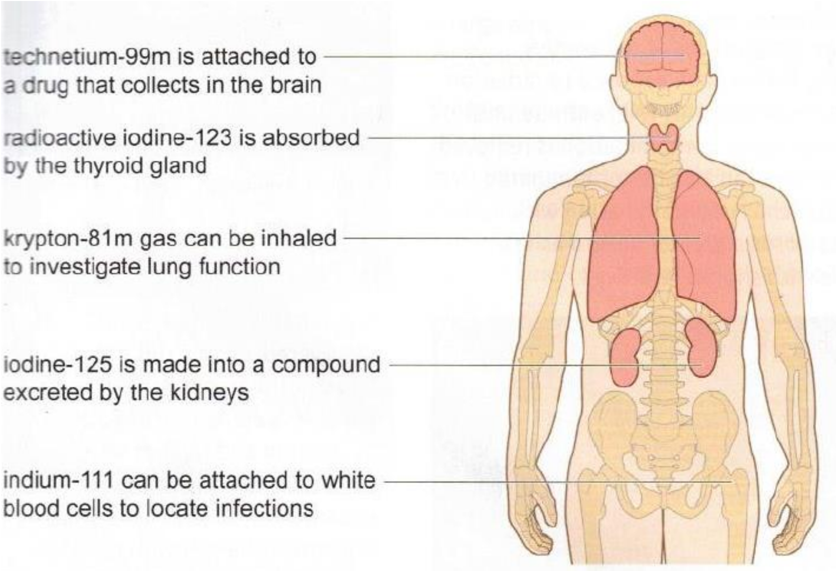


D how a smoke alarm works

Checkpoint

How confidently can you answer the Progression questions?

Medical Diagnosis and Treatment Using Radiation

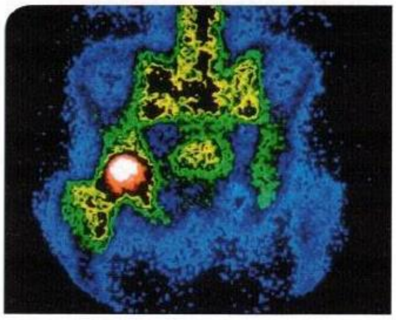


A Different tracers are absorbed by different parts of the body.

Diagnosing with gamma rays

Radioactive materials are used to diagnose medical conditions without having to cut into a patient's body. A radioactive tracer, which emits gamma rays, is put into the patient.

Tracers often contain a radioactive isotope attached to molecules that will be taken up by particular organs in the body. The tracer is usually injected into the bloodstream, but it may be swallowed, inhaled or injected directly into an organ. The location of the tracer in the body is detected using one or more **gamma cameras**.



B This gamma camera scan shows a bone tumour. The brighter the colour, the more radiation has been detected.

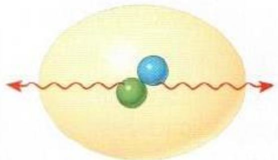
Tracers can be injected into the blood to find sources of internal bleeding. Gamma cameras detect the area of highest gamma radiation, which is where the bleeding is occurring.

Gamma cameras are also used to detect **tumours**. The tracer is made using radioactive glucose molecules because very active cells, such as cancer cells, take up glucose more quickly than other cells.

6th **1** Name two medical conditions that can be investigated using gamma ray tracers.

8th **2** Look at photo B. Where is the main cancer in this person?

8th **3** Why are alpha and beta sources not used in medical radioactive tracers?



C The electron-positron annihilation causes two gamma rays to be emitted in opposite directions.

Diagnosing with positrons

Tracers that emit positrons can also be used to detect medical problems. The tracer emits a positron. When this meets an electron, both it and the electron are destroyed and two gamma rays are emitted in opposite directions. The detector in a **PET scanner** moves around the patient, building up a set of images showing where different amounts of gamma radiation are coming from.

The radioactive isotopes used in all medical tracers need to have a short half-life so that other parts of the body are affected as little as possible. This means that they lose their radioactivity quickly and so must be made close to the hospital. They are often used within hours or even minutes of production.

9th **4** Radioactive isotopes are produced in cyclotrons. Suggest why cyclotrons are located around the UK, sometimes within hospitals.

Treating cancer

Cancer cells divide more rapidly than most other cells in the body and so are more susceptible to being killed by radiation.

Internal radiotherapy uses a beta emitter such as iodine-131 placed inside the body, within or very close to a tumour. This does not always require surgery – the patient stays in a room alone while the source is in place.

7th **5** Suggest why patients are kept away from other people while being treated with internal radiotherapy.

Most radiotherapy is **external radiotherapy**, which uses beams of gamma rays, X-rays or protons directed at the tumour from outside the body. Several lower strength beams may be directed at the tumour from different directions so that only the tumour absorbs a lot of the energy and the surrounding tissues are harmed as little as possible.

Checkpoint

How confidently can you answer the Progression questions?

Strengthen

S1 Describe two ways in which radiation is used to diagnose medical conditions.

S2 Write down one similarity and one difference between internal and external radiotherapy.