

Applications of Radioactivity

Physics Year 11 Term 2 Week 10

Radiotherapy

High doses of radiation can causes the normal functioning of living cells to change. This can lead to abnormal growth and cancer. Very high doses will kill cells.

Conversely cancer cells can be targeted with radiation to reduce a tumour.

The radiation can be administered externally using gamma rays or internally with chemicals that emit alpha or beta radiation.



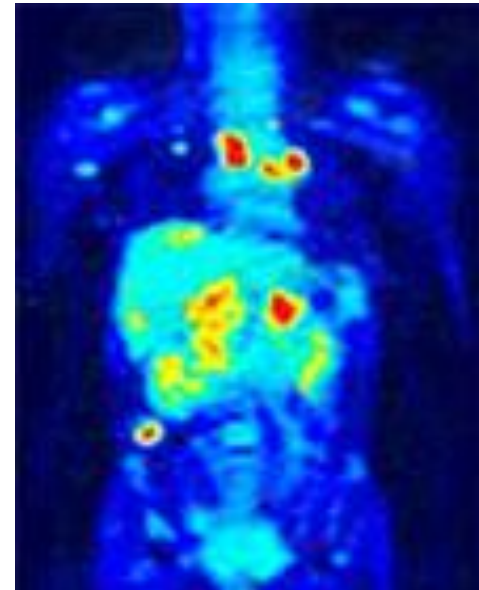
Gamma ray treatment

Medical Tracers in Diagnosis

Radioactive tracers are used to follow the flow of a substance through the body.

The gamma camera shown opposite can show where a patient has absorbed a tiny amount of radioactive substance.

Doctors can tell from the image obtained how well particular organs are functioning.



Properties required of the source

1. The source must emit **GAMMA** radiation.

Alpha or beta would not be able to pass out of the patient's body to the camera.

2. The source must have a long enough **half-life** to remain reasonably active over the period of observation
- but not too long so that it does not irradiate the patient's body for a longer than needed.

3. The radioactive substance must not be toxic nor decay into a substance that is toxic or radioactive.

4. Isotopes used include Iodine-123, half-life 13 hours and a form of Technetium-99 that has a gamma emission half-life of 6 hours

Tracing Underground Leaks in Pipes



A radioactive tracer can be added to a fluid.

Where a leak occurs will be shown by an increase in the count rate detected.

Properties required of the source

1. The source must emit **BETA** radiation.

Alpha not be able to pass through the ground above the pipe.

Gamma radiation would give the same count rate whether or not a leak was present.

2. The source must have a long enough **half-life** to remain reasonably active over the period of investigation

- but not too long so that it does not remain a hazard to the environment.

Choose appropriate words to fill in the gaps below:

A radioactive tracer can be used to detect leakages in underground pipes. A beta source is added to the liquid being transported by the pipe. The ground around the leak will therefore become radioactive.

The source must produce beta radiation because alpha radiation would be able to penetrate the ground above the pipe to be detected.

The half-life of the source must be long enough for it to remain detectable but not too long as to cause long term radioactivity in the ground.

WORD SELECTION:

half-life detectable radioactive beta alpha penetrate tracer

Sterilisation

Micro-organisms on medical instruments such as plastic syringes can be killed using a strongly ionising source of radiation. This is called **sterilisation**.

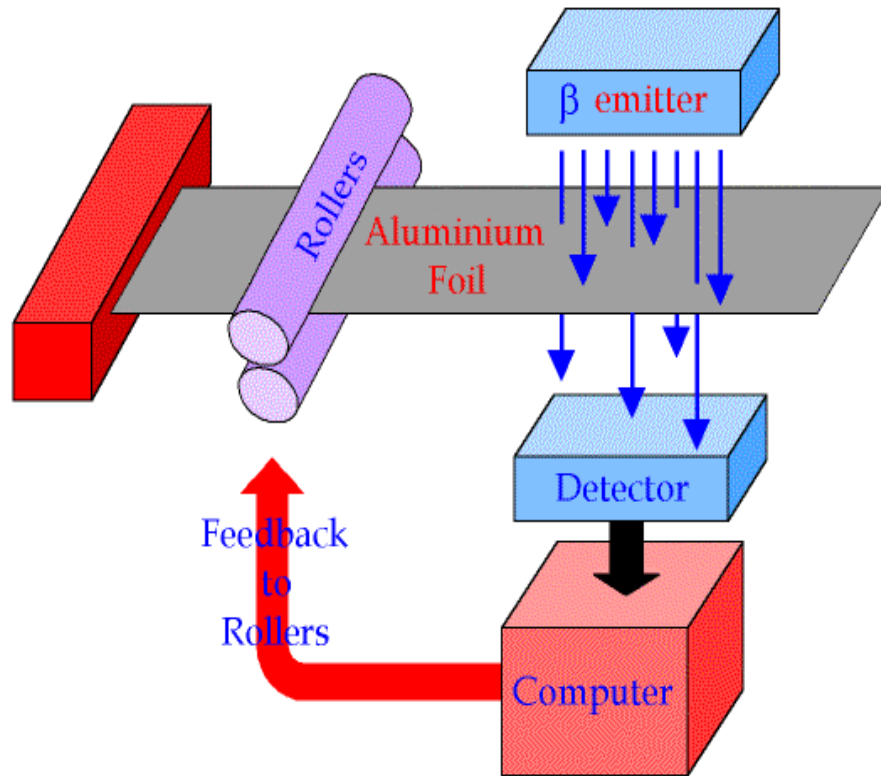
This process can be used on medical instruments while they are still within their packaging.

The lifetime of food can also be increased by irradiation.



Sterile syringe within its packaging

Automatic thickness monitoring



The amount of radiation received by the detector depends on the thickness of the aluminium foil.

If the thickness increases then the detector reading falls.

This will cause the computer to bring the rollers closer together and so decrease the foil thickness.

Properties required of the source

A source of **BETA** radiation must be used.

Alpha would not pass through the thinnest aluminium.

Gamma would not be affected by any thickness change.

A **LONG HALF-LIFE** source must be used.

- or else a false thickness increase will be detected as the activity of the source decreases.

A suitable isotope is Strontium-90, a beta emitter with a half-life of 29 years.

Smoke detectors



A radioactive source inside the alarm ionises an air gap so that it conducts electricity.

In a fire, smoke prevents the radiation causing ionisation.

The drop in electric current caused sets off the alarm.

Properties required of the source

A source of **ALPHA** radiation must be used.

- beta or gamma would not cause sufficient ionisation nor would they be affected by smoke.

A **LONG HALF-LIFE** source must be used.

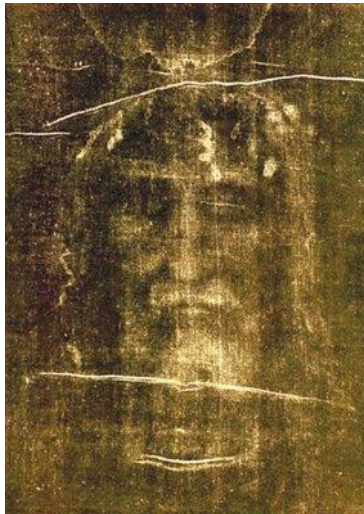
- or else a drop in current would set off the alarm.

The commonly used isotope is Americium-241, an alpha emitter with a half-life of 433 years.

Radioactive dating



Radioactive Carbon-14 has been used to try to find the age of the Turin Shroud

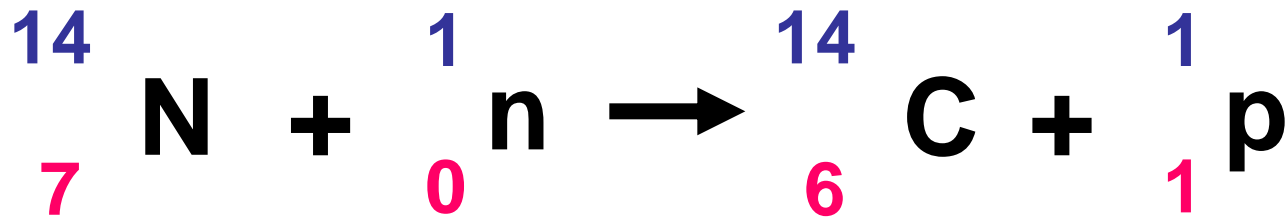


Uranium in rocks can be used to date formations such as the Grand Canyon



Radiocarbon dating

Living material (for example a plant) contains a known tiny proportion of radioactive carbon-14. This isotope is produced when high speed neutrons (part of cosmic radiation) collide with nitrogen gas in our atmosphere.



Carbon-14 decays by beta emission back to the stable nitrogen-14 with a half-life of about 5600 years.

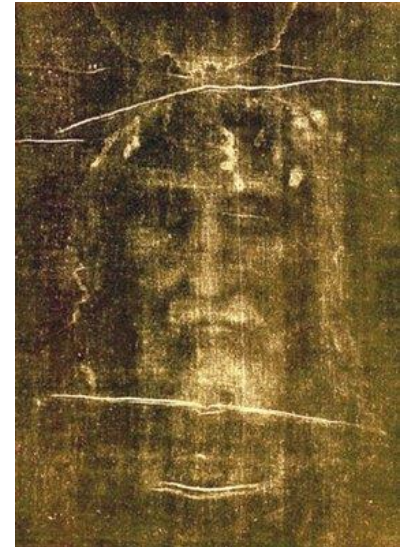


Carbon-14 is chemically identical to the non-radioactive carbon-12. Plants absorb carbon-14 during the process of photosynthesis.

All living material will contain a certain proportion of carbon-14 as will any animals that eat these plants.

When the plant or animal dies it no longer absorbs any more carbon-14. Therefore the proportion of amount of radioactive carbon decreases.

The age of the once living material can be estimated by comparing its residual radioactive carbon content with that of living material.



Radiocarbon dating has estimated that the age of the Turin Shroud is only about one thousand years – but this is disputed.

Limitations of radiocarbon dating

The dating process assumes that the level of cosmic radiation reaching the Earth is constant.

This can be corrected for by using objects of known age such as the mummies of Egyptian Pharaohs and the no longer living parts of ancient living trees.

Radiocarbon dating is limited to samples no older than about 60 000 years (about 10 half-lives) beyond which the amount of carbon-14 in the source becomes too small to measure accurately.

Radiocarbon dating question

360 g of living wood has an activity 72Bq (after deducting background radiation). A 360g sample of wood from an archaeological site is found to have an activity of 9Bq. Estimate the age of the wood if carbon-14 has a half-life of 5600 years.

$$\frac{1}{2} \times 72 = 36$$

$$\frac{1}{2} \times 36 = 18$$

$$\frac{1}{2} \times 18 = 9$$

The wood has undergone 3 half-lives
= 3 x 5600 years

Estimated age of wood = 16 800 years

Have a good holiday!

Remember to have a look at the
practise questions and tests
before you return!

Dating rocks

There are a number of techniques that involve comparing the relative proportions of the elements found in a rock sample.

When formed the rock may contain a radioactive isotope such as uranium-238. This is called the **parent nuclide**.

Over time this decays to thorium-234, which itself decays by various stages until the stable isotope lead-206 is formed. These are all called **daughter nuclides**.

The older the rock sample the greater will be the lead-206 content.



Uranium dating is one of the methods used to estimate the age of the Earth

Rock dating half-lives

The half-lives in the table below shows the time taken for half of the parent nuclei to decay into the final stable daughter nuclei.

Parent isotope	Stable daughter isotope	Half-life (years)
uranium-238	lead-206	4.47 billion
uranium-235	lead-207	704 billion
thorium-232	lead-208	14 billion
potassium-40	argon-40	1.25 billion

Rock dating question

A non-porous sample of igneous rock contains three times as much argon-40 as potassium-40. Estimate the age of this rock. Potassium-40 has a half-life of 1.25 billion years.

Assuming that the rock was formed without any argon-40
After 1.25 billion years there would be:

50% potassium and 50% argon

After 2 x 1.25 billion years there would be:

25% potassium and 75% argon

This is the current ratio

Estimated age of the rock = 2.5 billion years

Hazards of nuclear radiation

The ionisation caused by radiation can damage or kill living cells.

This can lead to genetic mutation or cancerous growth.

Alpha particles cause the greatest amount of ionisation and are therefore potentially the most dangerous type of radiation. They are, however, the easiest to shield against.



Safety precautions

The main precaution is to reduce the dosage received to the minimum possible.

To achieve this radioactive sources should:

- be stored in a lead-lined container
- be handled for the minimum possible time
- be handled only with tongs
- never be pointed at anyone
- never be put in pockets
- be checked by looking at them in a mirror



Problems with nuclear waste

Nuclear waste is radioactive and may have to be stored safely for thousands of years.

The waste is stored underground in sealed containers that must be capable of containing the radioactivity for thousands of years.

Suitable sites also must be found free of the effects of earthquakes or ground water leakage.



Choose appropriate words to fill in the gaps below:

Radioactivity can be used to date materials.

Radiocarbon dating uses the proportion of radioactive carbon-14 to stable carbon-12 in a former living sample.

Rocks can be dated using the parent isotope uranium-238 and its stable daughter isotope lead-206.

Radioactivity causes ionisation which can cause living cells to undergo genetic mutation leading on to possibly cancerous growth. It is therefore important to minimise exposure especially to alpha particles which cause the most intense ionisation.

WORD SELECTION:

carbon-14 daughter ionisation date parent
alpha proportion mutation carbon-12