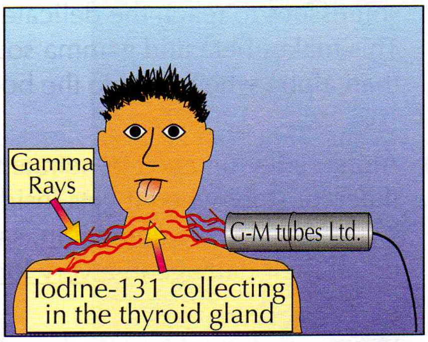
Uses of Nuclear Radiation

***Medical tracers** use **beta** or **gamma** radiation*

Beta and gamma radiation will penetrate the skin and other body tissues. This makes them suitable for using as medical tracers...

1) A source which emits β or γ radiation is injected into the patient (or just swallowed). The radiation penetrates the body tissues and can be detected externally. As the source moves around the body, the radiographer uses a detector to monitor its progress or to get a 'snapshot' of its distribution.



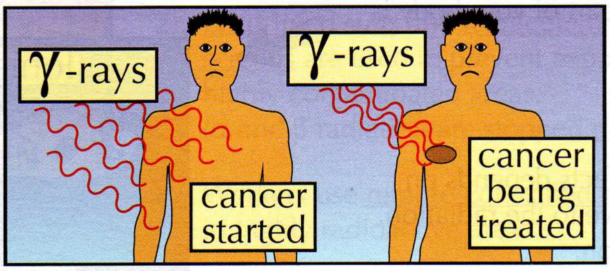
2) A computer converts the reading to an on-screen display showing where the radiation is coming from. Doctors use this method to check whether the organs of the body are working as they should.

3) The radioactive source has to have a short half-life, so you can use less of the radioactive source but still get a reading on your detector.

4) An alpha source would be worse than useless as a medical tracer — useless because it would be stopped by the body's tissues, so you'd never detect it externally, and worse than useless because its strong ionising power makes alpha radiation really harmful if it gets inside you (see next page).

Gamma** radiation is also used to **treat cancer

Radiation can damage living cells (see next page) and cause cancer. Once cancer's started, patients are often given radiotherapy to kill the cancer cells and stop them dividing. This involves using a high dose of gamma rays, carefully directed to zap the cells in the tumour while minimising the dose to the rest of the body.



The isotope you use depends on half-life and whether it's α, β or γ

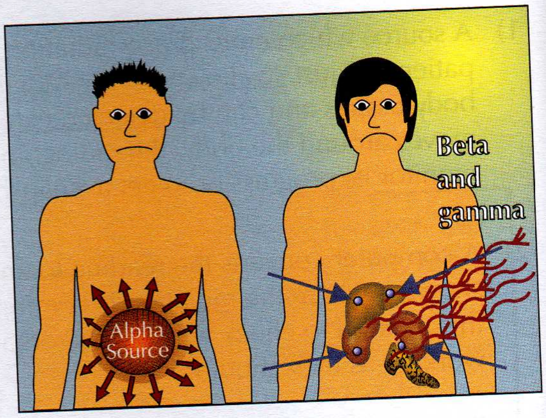
Knowing the detail is important here. For instance, swallowing an alpha source as a medical tracer would be very foolish — alpha radiation would cause all sorts of chaos inside your body but couldn't be detected outside, making the whole thing pointless. So learn what each type's used for and why.

Risks from Nuclear Radiation

Nuclear radiation can do nasty stuff to living cells so you have to be careful how you handle it. The effect of radiation on cells depends on the type of radiation and the size of the dose.

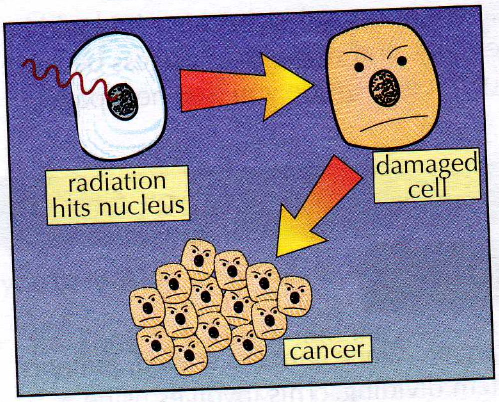
Radiation harms living cells

1) Beta and gamma radiation can penetrate the skin and soft tissues to reach the delicate organs inside the body. This makes beta and gamma sources more hazardous than alpha when outside the body.



2) Alpha radiation can't penetrate the skin, but it's a different story when it gets inside your body (by swallowing or breathing it in, say) — alpha sources do all their damage in a very localised area.

3) Beta and gamma sources, however, are less dangerous inside the body — their radiation mostly passes straight out without doing much.

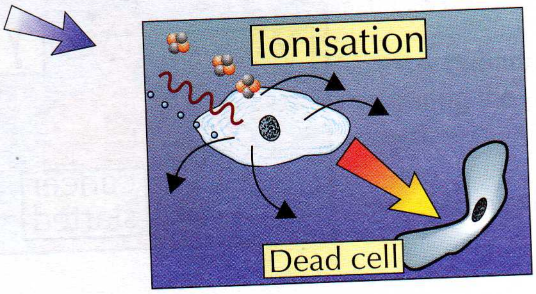


4) If radiation enters your body, it will collide with molecules in your cells.

5) These collisions cause ionisation, which damages or destroys the molecules.

6) Lower doses tend to cause minor damage without killing the cell. This can give rise to mutant cells which divide uncontrollably — this is cancer.

7) Higher doses tend to kill cells completely, causing radiation sickness if a large part of your body is affected at the same time.



8) The extent of the harmful effects depends on how much exposure you have to the radiation, and its energy and penetration.

Nuclear radiation + living cells = cell damage, cell death or cancer

Most people could probably tell you that nuclear radiation is dangerous — what you need to know is what radiation can do to living cells and why the three types of radiation have different effects. Check out pages 49-50 if you're having trouble remembering the properties of the different radiation types.

Risks from Nuclear Radiation

You've got to be really careful with anything radioactive — no mucking about.

*You should **protect yourself** in the **laboratory**...*

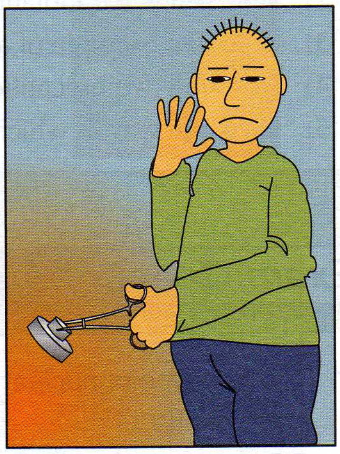
You should always act to minimise your exposure to radioactive sources.

1) Never allow skin contact with a source. Always handle sources with tongs.

2) Keep the source at arm's length to keep it as far from the body as possible.

3) Keep the source pointing away from the body and avoid looking directly at it.

4) Always keep the source in a labelled lead box and put it back in as soon as the experiment is over, to keep your exposure time short.



*...and if you **work** with **nuclear radiation***

1) Industrial nuclear workers wear full protective suits to prevent tiny radioactive particles being inhaled or lodging on the skin or under fingernails, etc.

2) Lead-lined suits and lead/concrete barriers and thick lead screens are used to prevent exposure to gamma rays from highly contaminated areas. (α and β radiation are stopped much more easily.)

3) Workers use remote-controlled robot arms to carry out tasks in highly radioactive areas.

Radiation's dangerous stuff — safety precautions are crucial

It's quite difficult to do research on how radiation affects humans. This is partly because it would be unethical to do controlled experiments, exposing people to huge doses of radiation just to see what happens. We rely mostly on studies of populations affected by nuclear accidents or nuclear bombs.

Warm-Up and Exam Questions

Imagine if you opened up your exam paper and all the answers were already written in for you. Hmm, well I'm afraid that won't happen, so the only way you'll do well is through some hard work now.

Warm-Up Questions

1) How do smoke detectors work?
2) Why is nuclear radiation dangerous?
3) Give one example of a medical use of nuclear radiation.
4) Describe two precautions that should be taken when handling radioactive sources in the lab.
5) Give one way in which workers in nuclear power plants can be protected from radiation.

Exam Questions

1 Which type of nuclear radiation is the most dangerous inside the body?

A alpha
B beta
C gamma
D neutron

(1 mark)

2 Which of the following is **not** a use of gamma radiation?

A industrial tracers
B smoke detectors
C medical tracers
D sterilising machines

(1 mark)

3 Nuclear radiation has many uses within medicine.

(a) Give two reasons why alpha sources aren't used as medical tracers. *(2 marks)*

(b) Why is it important that radioactive sources used in hospital sterilising machines have a long half-life? *(1 mark)*

(c) Why is the dose of radiation given in radiotherapy directed only at the tumour? *(1 mark)*

4 Nuclear radiation can have harmful effects on the human body.

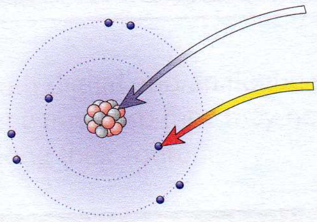
a) Briefly explain how a low dose of nuclear radiation can cause cancer. *(2 marks)*

b) Describe what can happen to the body if it receives a very high dose of nuclear radiation. *(1 mark)*

Radioactivity

Nuclear radiation is different from EM radiation. So you do need to read these next few pages. Sorry.

Nuclei contain protons and neutrons

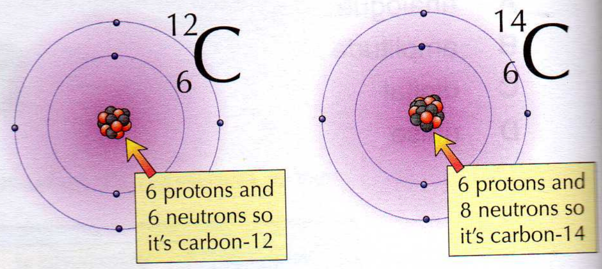


The nucleus contains protons and neutrons. It makes up most of the mass of the atom, but takes up virtually no space — it's tiny.

The electrons are negatively charged and really really small. They whizz around the outside of the atom. Their paths take up a lot of space, giving the atom its overall size (though it's mostly empty space).

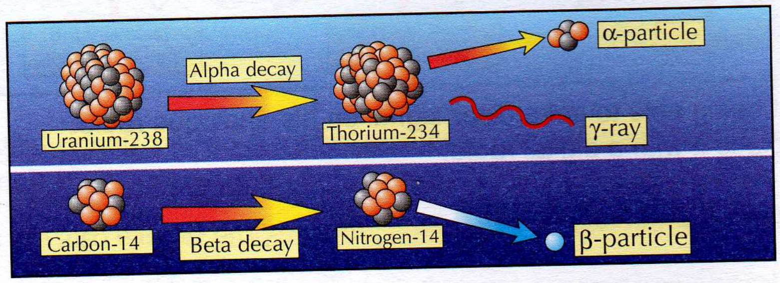
Isotopes are atoms with different numbers of neutrons

1) Many elements have a few different isotopes. Isotopes are atoms with the same number of protons but a different number of neutrons.
2) E.g. there are two common isotopes of carbon. The carbon-14 isotope has two more neutrons than 'normal' carbon (carbon-12).
3) Usually each element only has one or two stable isotopes — like carbon-12. The other isotopes tend to be radioactive — the nucleus is unstable, so it decays (breaks down) and emits radiation. Carbon-14 is an unstable isotope of carbon.



Radioactive decay is a random process

1) The nuclei of unstable isotopes break down at random. If you have 100 unstable nuclei, you can't say when any one of them is going to decay, and you can't do anything to make a decay happen.
2) Each nucleus just decays quite spontaneously in its own good time. It's completely unaffected by physical conditions like temperature or any sort of chemical bonding etc.



3) When the nucleus does decay it spits out one or more of the three types of radiation — alpha, beta and gamma (see pages 49-50).
4) In the process, the nucleus often changes into a new element.

Protons determine the element, neutrons determine the isotope...

This isotope business can be a bit confusing at first, as you can have different isotopes which are all the same element. Remember, it's the number of protons which decides what element it is, then the number of neutrons decides what isotope of that element it is.

Radioactivity

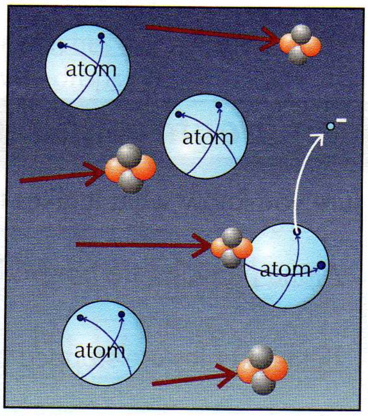
There are three types of radiation — alpha (α), beta (β) (on this page) and gamma (γ) (on the next page). You need to remember what they are, how well they penetrate materials (including air), and their ionising power.

Nuclear radiation causes ionisation

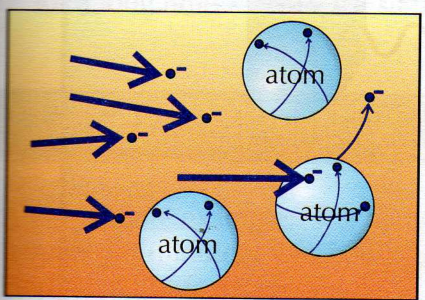
1) Nuclear radiation causes ionisation by bashing into atoms and knocking electrons off them. Atoms (with no overall charge) are turned into ions (which are charged) — hence the term "ionisation".
2) There's a pattern: the further the radiation can penetrate before hitting an atom and getting stopped, the less damage it will do along the way and so the less ionising it is.

Alpha particles are helium nuclei → ${}^{4}_{2}He$

1) Alpha particles are made up of 2 protons and 2 neutrons — they're big, heavy and slow-moving.
2) They therefore don't penetrate far into materials but are stopped quickly.
3) Because of their size they bash into a lot of atoms and knock electrons off them before they slow down, which creates lots of ions.
4) Because they're electrically charged (with a positive charge), alpha particles are deflected (their direction changes) by electric and magnetic fields.



Beta particles are electrons → ${}^{0}_{-1}e$



1) A beta particle is an electron which has been emitted from the nucleus of an atom when a neutron turns into a proton and an electron. So for every β-particle emitted, the number of protons in the nucleus increases by 1.
2) They move quite fast and they are quite small.
3) They penetrate moderately before colliding and are moderately ionising too.
4) Because they're charged (negatively), beta particles are deflected by electric and magnetic fields.

Learning the types of radiation is as easy as α, β, γ

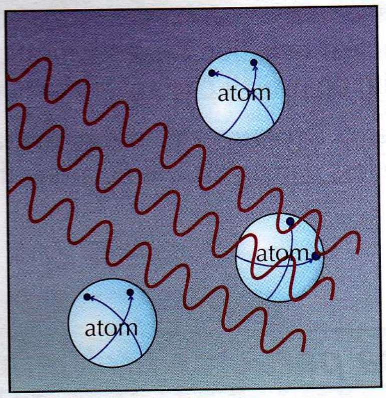
The symbols for alpha, beta and gamma radiation may look a little strange — but really they're just a, b and c written using the Greek alphabet. True it might be easier to use a, b and c, but the Greek letters have been used for so long now that it'd confuse more people than it would help, sorry.

Radioactivity

Gamma radiation is quite different from alpha and beta radiation. Gamma rays are part of the electromagnetic spectrum — just like light and radio waves.

Gamma rays are very short wavelength EM waves

1) In a way, gamma rays are the opposite of alpha particles. They have no mass — they're just energy (in the form of an EM wave — see page 37).
2) They penetrate a long way into materials without being stopped.
3) This means they are weakly ionising because they tend to pass through rather than collide with atoms. But eventually they hit something and do damage.
4) Gamma rays have no charge, so they're not deflected by electric or magnetic fields.



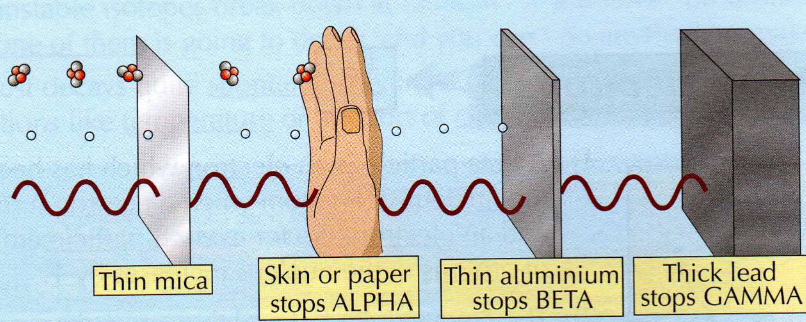
You can identify the type by what blocks it

Make sure you know what it takes to block each of the three types of radiation:

Alpha particles are blocked by paper, skin or a few centimetres of air.

Beta particles are stopped by thin metal.

Gamma rays are blocked by thick lead or very thick concrete.



So if radiation can penetrate paper it could be beta or gamma — you'd have to test it with a metal, say, to find out which.

Remember — alpha penetrates least, gamma penetrates most

Remember: alpha's big, slow and clumsy — always knocking into things. Beta's lightweight and fast, and gamma weighs nothing and moves super-fast. Practise with this: if it gets through paper and is deflected by a magnetic field, it must be ________________ radiation. (Answer on page 221.)

Warm-Up and Exam Questions

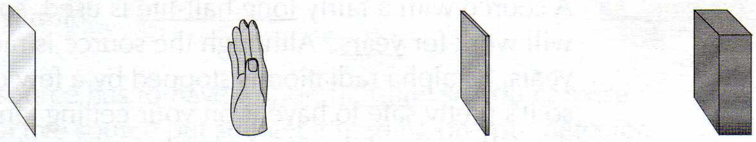
There's no point in skimming through the section and glancing over the questions. Do the warm-up questions and go back over any bits you don't know. Then try the exam questions — without cheating.

Warm-Up Questions

1) Explain what isotopes are.
2) What is meant by 'radioactive decay'?
3) Name the three types of nuclear radiation.
4) Which type of nuclear radiation is also a type of electromagnetic radiation?

Exam Questions

1 The diagram shows four different materials.



thin mica 1 | skin 2 | aluminium 3 | thick lead 4

Match up the materials 1-4 with these descriptions.

A Stops all types of nuclear radiation.
B Doesn't stop any types of nuclear radiation.
C Stops alpha and beta radiation.
D Stops only alpha radiation.

(4 marks)

2 An alpha particle is
A a proton
B a neutron
C a helium nucleus
D an electromagnetic wave

(1 mark)

3 A sample of a highly ionising radioactive gas has a half-life of two minutes.

(a) What does 'half-life' mean?

(1 mark)

(b) What fraction of the radioactive atoms currently present will be left after four minutes?

(1 mark)

(c) When an atom of the gas decays, it releases an electron. What type of nuclear radiation does this gas emit?

(1 mark)

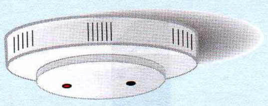
Uses of Nuclear Radiation

Radiation's useful in all sorts of ways, but choose carefully — you need to use a source which emits the right type of radiation and has a suitable half-life.

You need a long half-life for devices that have to last

1) Sterilising machines in hospitals use gamma radiation to kill bacteria on medical instruments. They use a powerful radioactive source with a long half-life, so that it lasts for a long time.

2) Smoke detectors use a weak source of alpha radiation to ionise the air between two electrodes — making charged particles which carry a current. If there's a fire, the smoke absorbs the radiation — the current stops and the alarm sounds.

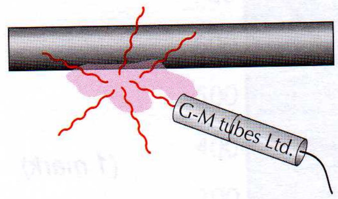


A source with a fairly long half-life is used, so that the detector will work for years. Although the source is radioactive for years, its alpha radiation is stopped by a few centimetres of air, so it's pretty safe to have it on your ceiling (and much better than sleeping while your house burns).

Gamma radiation is used in industrial tracers

If you're looking for a leak in an underground pipe, you could dig it up, or you could use gamma rays...

1) You squirt a γ-source into the pipe, let it flow along, and go along the outside with a detector.
2) Gamma radiation will penetrate through a metal pipe, but some of it gets absorbed — exactly how much depends on the thickness of the pipe and what it's made of.



3) If there's a crack in the pipe, the γ–source will collect outside the pipe and your detector will show extra high radioactivity at that point.
4) The isotope used must be a gamma emitter, so that the radiation can be detected even through any rocks or earth surrounding the pipe — alpha and beta radiation would be too easily blocked.
5) It should also have a short half-life so as not to cause a long-term hazard if it collects somewhere.

Choose your source carefully

To make use of radiation, you've got to match the requirements of the job to the properties of your source. A γ-source in a smoke detector wouldn't work at all — gamma radiation wouldn't ionise the air, so there'd be no current, the alarm would ring constantly, and you'd get thoroughly irradiated.