Isotopes:
- Atoms that have the same number of protons (element), but different numbers of neutrons.

Key words:
1. Atoms - an atom has no overall charge.
3. Atomic number = protons (also = electrons).
4. Isotopes - atoms of the same element with the same numbers of protons and electrons but different numbers of neutrons.
5. Background radiation - low level radiation present at all times.
6. Irradiation - exposing an object to a radioactive source.
7. Contamination - unwanted radioactive atoms on an object.
8. Half-life - the time taken for the number of radioactive nuclei in a sample to halve.

Development of the model of the atom:
New experimental evidence may lead to the model being changed or replaced.

Early ideas:
Before the discovery of the electron atoms were tiny spheres, they couldn't be divided.

Plum pudding:
After the electron was discovered the atom became a ball of positive charge with negative electrons scattered in it.

Alpha particle scattering:
Showed that the mass of an atom was concentrated in the centre, it was charged too.

Niels Bohr:
Adapted the nuclear model suggesting electrons in orbitals at set distance.

James Chadwick:
Evidence to show the existence of neutrons in the nucleus.

Nucleus development:
Experiments now show nucleus is made of smaller particles of positive charge.

Mass number
(= protons + neutrons)

Atomic number
(= number of protons = number of electrons).

So in carbon:
Protons = 6
Electrons = 6 (same as protons)
Neutrons = 12 - 6 = 6
Comparing the nuclear model to the plum pudding model

<table>
<thead>
<tr>
<th>Nuclear Model</th>
<th>Plum Pudding model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where is the mass?</td>
<td>Concentrated in the centre/nucleus</td>
</tr>
<tr>
<td>Where is the positive charge?</td>
<td>Positive charge occupies a small part in the centre of the atom</td>
</tr>
<tr>
<td>Where are the electrons?</td>
<td>Electrons orbit some distance from the centre / electrons in shells</td>
</tr>
<tr>
<td>How much space is there?</td>
<td>The atom is mainly empty space</td>
</tr>
</tbody>
</table>

**Rutherford’s famous alpha particle experiment**
- Alpha particles were fired at gold foil
- Alpha particle have a positive charge as contain 2 protons and 2 neutrons and no electrons

**Observation**

<table>
<thead>
<tr>
<th>What it meant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most of the alpha particles went straight through the gold foil</td>
</tr>
<tr>
<td>Some of the particles were deflected</td>
</tr>
<tr>
<td>Very very few alpha particles reflected backwards</td>
</tr>
</tbody>
</table>
Nuclear Equations

Uranium-238 can decay into thorium-234 by emitting an alpha particle. Uranium has 92 protons and thorium has 90 protons.

![Alpha decay](image)

The nuclear equation for this decay looks like this:

\[
{\frac{238}{92}}U \rightarrow {\frac{234}{90}}Th + {\frac{4}{2}}He
\]

Carbon-14 can decay into nitrogen-14 by emitting a beta particle (when a neutron turns into a proton).

![Beta decay](image)

The equation is: \( ^{14}_6C \rightarrow ^{14}_7N + ^{0}_{-1}e \)

Half Life

The time taken for the number of radioactive nuclei in a sample to halve.

Sources of background radiation

- 31% radon gas
- 10% cosmic rays
- 12% food
- 14% rocks and building materials
- 1% the nuclear industry

Alpha (α) radiation

<table>
<thead>
<tr>
<th>Description</th>
<th>2 neutrons, 2 protons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric charge</td>
<td>+2</td>
</tr>
<tr>
<td>Relative atomic mass</td>
<td>4</td>
</tr>
<tr>
<td>Penetrating power</td>
<td>Stopped by paper or a few centimetres of air</td>
</tr>
<tr>
<td>Ionizing effect</td>
<td>Strongly ionizing</td>
</tr>
<tr>
<td>Effect of magnetic/electric field</td>
<td>Weakly deflected</td>
</tr>
</tbody>
</table>

Beta (β) radiation

<table>
<thead>
<tr>
<th>Description</th>
<th>High energy electron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric charge</td>
<td>-1</td>
</tr>
<tr>
<td>Relative atomic mass</td>
<td>1/1860</td>
</tr>
<tr>
<td>Penetrating power</td>
<td>Stopped by a few millimetres of aluminium</td>
</tr>
<tr>
<td>Ionizing effect</td>
<td>Weakly ionizing</td>
</tr>
<tr>
<td>Effect of magnetic/electric field</td>
<td>Strongly deflected</td>
</tr>
</tbody>
</table>

Gamma (γ) radiation

<table>
<thead>
<tr>
<th>Description</th>
<th>High energy electromagnetic radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric charge</td>
<td>0</td>
</tr>
<tr>
<td>Relative atomic mass</td>
<td>0</td>
</tr>
<tr>
<td>Penetrating power</td>
<td>Stopped by several centimetres of lead or several metres of concrete</td>
</tr>
<tr>
<td>Ionizing effect</td>
<td>Very weakly ionizing</td>
</tr>
<tr>
<td>Effect of magnetic/electric field</td>
<td>Not deflected</td>
</tr>
</tbody>
</table>

Gamma radiation can give rise to mutant cells which divide uncontrollably — see Figure 1. The cells keep dividing, making more cells and forming a tumour — this uncontrolled cell division is cancer.

The initial activity is 80, so after one half-life it will be 40 (and after two it will be 20 and after three it will be 10).

To find the half-life of the sample, draw a line from 40 on the activity axis across to the curve and down to the time axis (green dotted line). This tells you that the half-life is 4 hours.

You can check you were right by doing the same for an activity of 20 and checking that you get a time of 8, and so on...
Irradiation
This is where an object is exposed to radiation
Most background radiation is harmless
Some irradiation such as from X-Rays or
irradiation of medical equipment to kill bacteria
and sterilise it or used in the food industry to
make sure the food does not spoil has such a
short half life it is not harmful

Radiation causes the DNA to become
ionised, this breaks and damages the
DNA. The cell can die or it can
undergo repair. If it is repaired
accurately the cell functions
normally. It can undergo misrepair
which can lead to the cells developing
into cancer.

What is radioactive contamination and why it is a hazard
and why contamination from an alpha emitter is much
more dangerous than the other sources of radiation:
• It is unwanted presence of radioactive atoms.
• From coming into contact through touching, ingesting or
breathing something in
• Radioactive atoms can ionise cells causing damage to cell
DNA
• This can result in mutations in the DNA and genes or
cancer
• Alpha is the most ionising radiation and least penetrative
• This means it gets stuck and ionises all the cells it comes
in to contact with
Brachytherapy
This is where a small sealed radioactive source or seed is placed in to the tumour itself, to give a high dose of radiotherapy directly to the tumour but a much lower dose to the surrounding tissues. Brachytherapy is mainly mused to treat cancers in the prostate gland, cervix and womb. It is sometimes given in addition to radiotherapy.

Radiotherapy
• 3 sources of radiation (X-ray) are arranged around a patients head
• Each carrying 1/3rd of the dose.
• The healthy tissue it travels through will also be destroyed or damaged
• To prevent this the sources are rotated
• So the tumour receives constant radiation
• The surrounding tissues receive only 1/3rd but not all the time
• X rays used as can control the amount of energy given off

What is peer review?
When scientists were investigating nuclear radiation they were unaware on its effect on health and many died as a result. When the first atomic bombs exploded they did not understand the effects not on just immediate health but the health of generations of people and the effect long term on that area Peer review allows scientists to try to repeat others results and check the results

Choosing a tracer
All isotopes which are taken into the body must be gamma or beta emitters, so that the radiation passes out of the body. Alpha sources should never be used as they are highly ionising and do damage in a localised area. The source should only last a few hours too, so that the radioactivity inside the patient quickly disappears.

How can a radioactive tracer be used to diagnose a blocked blood vessel?
• Measure the background radiation so you don’t take this into account for your experiment and know the actual radiation emitted from the source
• The radioisotope would be injected into the blood vessel
• Using a Geiger counter we would measure the radiation from outside the body as it moved through the blood vessel
• If the radiation stopped moving at a certain point this would indicate the location of the blockage
• Gamma radiation is used as it is the least ionising to cells
• This means it will cause the least damage to surrounding cells
• Gamma is also the most penetrative so will be detected outside the body
In order to do fusion you have to fuse 2 nuclei, both have a positive charge and repel each other. Very large amounts of energy are required to do this e.g. in the sun. This is how new elements are formed. The larger the 2 elements that are trying to fuse together the more energy required to overcome the 2 positively charged nuclei.

Medical uses of radiation

Although ionising radiation can be harmful to living cells, it can also have its benefits if used correctly.

Medical tracers

Certain radioactive isotopes can be injected into people (or they can just swallow them) and their progress around the body can be followed using an external detector. These isotopes are known as medical tracers. A computer converts the readings from the external detector to a display showing where the strongest readings are coming from. This can help doctors to investigate whether the patient's internal organs are functioning as they should be.

Nuclear fission

Nuclear fission is a type of nuclear reaction that is used to release energy from large and unstable atoms (e.g. uranium or plutonium) by splitting them into smaller atoms.

Spontaneous (unforced) fission rarely happens. Usually, the nucleus has to absorb a neutron before it will split. When the atom splits, it forms two new lighter elements that are roughly the same size (and that have some energy in their kinetic energy stores).

Two or three neutrons are also released when an atom splits. If any of these neutrons are moving slowly enough to be absorbed by another nucleus, they can cause more fission to occur. This is a chain reaction. It is this process which is used to generate power in a nuclear power plant.

The amount of energy released by fission in a nuclear reactor is controlled by changing how quickly the chain reaction can occur. This is done using control rods, which are lowered and raised inside the nuclear reactors to absorb neutrons, slow down the chain reaction and control the amount of energy released.

Uncontrolled chain reactions quickly lead to lots of energy being released as a nuclear explosion — this is how atomic bombs work.
1. Explain what is meant by ionising
2. Explain what is meant by penetrative
3. Explain the differences between alpha, beta and gamma radiation
4. Explain the developments that led to the current model of the atom
5. Explain Rutherford’s famous experiment
6. Explain how his experiment disproved the plum pudding experiment
7. Compare the plum pudding model to the nuclear model
8. Explain what happens in alpha and beta decay
9. U-238 (atomic number = 92) undergoes 2 alpha then 1 beta decay, write out the 3 nuclear equations to show the decay
10. Explain the purpose of peer review
11. Explain what is meant by radioactive contamination
12. Explain what half life is
13. Explain how you can determine the half life of a substance from a graph
14. Caron-14 has a half-life of 5700 years. What fraction of its original activity will the sample have after 11 400 years?
15. How long will it take a sample of strontium-81 to decay to one eighth of its original value? (The half-life of strontium-81 is 22 minutes).
16. The activity of a neon-17 source is 1120Bq. What will it be after 0.5 seconds? (The half-life of neon-17 is 0.1 seconds).
17. The activity of an iridium-192 sample is 9600Bq. How long will it take to fall to 2400 decays per second? (The half-life of iridium-192 is 74 days).
18. An under floor fan is switched on to prevent any more radon-220 entering a house. The owner wants to know how long it will take for the radioactivity from the radon-220 in the house to fall to less than one thousandth of its original value. The half-life of radon-220 is one minute. How many half-lives will this take? How long will this take?
19. Explain how radiation can be used to treat cancer
20. Explain the difference between fission and fusion
21. Explain why large amounts of energy are required in a fusion reaction and why this is not possible on earth
22. Explain what a chain reaction is in a fission reaction
23. Explain how the chain reaction can be controlled in a nuclear reactor
The Atomic Model

1) Briefly explain how the model of an atom has changed over time.

2) What happens to an electron in an atom if it releases EM radiation?

3) Who provided evidence to suggest the existence of the neutron?

4) True or false? Atoms have no overall charge.

5) What happens to an atom if it loses one or more of its electrons?

Nuclear Decay and Half-life

6) Which number defines what element an atom is: the atomic number or the mass number?

7) What is the atomic number of an atom? What is the mass number of an atom?

8) What is an isotope? Are they usually stable?

9) What is radioactive decay?

10) Name four things that may be emitted during radioactive decay.

11) For the three types of ionising radiation, give: a) their ionising power, b) their range in air.

12) Explain why alpha radiation could not be used to check the thickness of metal sheets.

13) Draw the symbols for both alpha and beta radiation in nuclear equations.

14) What type of nuclear decay doesn’t change the mass or charge of the nucleus?

15) What is the activity of a source? What are its units?

16) Define half-life.

17) True or false? A short half-life means a small proportion of atoms are decaying per second.

18) Explain the dangers of a radioactive source with a long half-life.

19) Explain how you would find the half-life of a source, given a graph of its activity over time.
Dangers and Uses of Radiation

20) Define radiation dose.

21) State two aspects of your lifestyle that can affect your radiation dose.

22) Define irradiation and contamination.

23) Compare the hazards of being irradiated and contaminated by:
   a) an alpha source,  b) a gamma source.

24) Give two examples of how to protect against: a) contamination,  b) irradiation.

25) Describe some of the risks involved with using radiation.

26) Give two ways that radiation is used in medicine.

Fission and Fusion

27) Define fission and fusion.

28) True or false? Fission is usually spontaneous.

29) Describe what a chain reaction is, and what happens when it is uncontrolled.

30) Explain the difference between fission and fusion.