Uses of nuclear radiation

4.4.3.3 · Atomic structure · revision notes

How nuclear radiation is used in medicine to explore internal organs (tracers) and to control or destroy unwanted tissue (radiotherapy), and how to weigh up benefits against risks using data. Expect 'describe' and 'explain' questions and 6-mark 'evaluate' questions. GCSE Physics only, not in Combined Science.

Key facts

- Tracer: gamma emitter with a short half-life, detected outside the body by a gamma camera
- Radiotherapy: ionising radiation kills cancer cells
- Internal source: placed in or next to the tumour
- Gamma for tracers: passes out of the body and is weakly ionising
- External beams from several directions: large dose to tumour, smaller dose to healthy tissue
- Use radiation when the benefit is greater than the risk

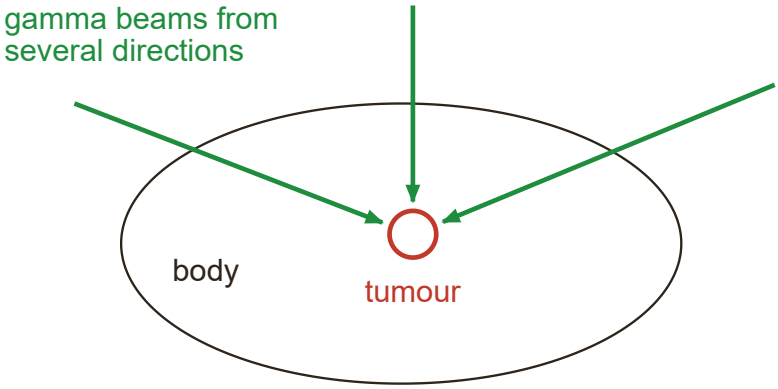
Notes

Exploring internal organs: tracers

- A **radioactive tracer** is swallowed or injected. It travels through the body to the organ being investigated.
- A detector outside the body (a **gamma camera**) builds up an image, showing how well the organ is working or where there is a problem.
- The tracer should emit **gamma** rays: they pass out of the body to the detector, and they are weakly ionising, so they do little damage.
- It should have a **short half-life** (a few hours), so the activity in the body soon falls. Technetium-99m (half-life about 6 hours) is widely used.
- The thyroid gland absorbs iodine, so a radioactive isotope of iodine can be used to examine it.

Controlling or destroying unwanted tissue

- Ionising radiation damages and kills cells, so it can be used to destroy cancer cells. This is **radiotherapy**.
- External: beams of gamma rays are aimed at the tumour from several directions (the source moves around the patient). The tumour gets a large dose; healthy tissue gets a smaller one.



each part of the healthy tissue gets only a small dose

The beams overlap only at the tumour, so it gets a large dose.

- Internal: a small radioactive source is placed in or next to the tumour, so most of the radiation is absorbed by the tumour cells.
- Radioactive iodine can be swallowed to destroy unwanted thyroid tissue, because the thyroid absorbs iodine.

Weighing up the risks

- Any exposure to ionising radiation carries some risk: it can damage or kill healthy cells and cause mutations in DNA, leading to cancer or radiation sickness.
- The greater the activity of the source, and the longer the exposure, the greater the risk of harm.
- Radiation is used when the benefit, such as diagnosing or treating a serious illness, is greater than the risk.
- Perceived risk is how dangerous people think something is. It can differ from the real risk shown by data, so compare doses, e.g. with the yearly dose from background radiation.

How to answer each type of question

Explain why an isotope is suitable as a tracer

3 to 4 marks | **Grade 6**

1. Take each property given in the question in turn.
2. Gamma: passes out of the body to the detector; weakly ionising.
3. Half-life: long enough for the scan, short enough for a small dose.

Example. Technetium-99m is used as a medical tracer. It emits gamma rays and has a half-life of 6 hours.
Explain why these properties make it suitable.

Model answer. Gamma rays can pass out of the body (1), so they can be detected outside the body (1). Gamma is weakly ionising, so it does little damage to cells (1). A 6-hour half-life is long enough to carry out the scan, but the activity falls quickly, so the patient's dose is small (1).

Describe how radiotherapy treats a tumour

3 marks | Grade 7

1. Say what radiation is used and where it is aimed.
2. Say that it comes from several directions.
3. Explain the result for the tumour and for healthy tissue.

Example. Describe how gamma radiation can be used to destroy a tumour while reducing damage to healthy tissue.

Model answer. Beams of gamma rays are aimed at the tumour (1) from several different directions (the source moves around the patient) (1). The beams overlap at the tumour, so it receives a large dose that kills its cells, while each area of healthy tissue receives a much smaller dose (1).

6-mark: evaluate a medical use of radiation

6 marks (level of response) | Grade 8

1. Give the benefits, using the context.
2. Give the risks, explaining why ionising radiation is harmful.
3. Use the data, e.g. compare the dose with the yearly background dose.
4. Finish with a conclusion that follows from your points.

Example. A doctor suggests a scan using a radioactive tracer that emits gamma rays and has a half-life of 6 hours. The scan can find a serious illness early, when it is easier to treat. The scan gives a dose of 4 mSv. The average yearly dose from background radiation is 2.5 mSv.
Evaluate the use of this scan.

Model answer.

Model answer: The main benefit is that a serious illness can be found early, when it is easier to treat, which could save the patient's life. The tracer emits gamma rays, which pass out of the body to the camera and are weakly ionising, and its short half-life means the activity in the body soon falls. The risk is that the radiation is ionising, so it could damage healthy cells or DNA and slightly increase the risk of cancer. The dose of 4 mSv is 4 ÷ 2.5 = 1.6 times the average yearly background dose, so it is extra radiation, but it is still a small dose. Overall, the small extra risk is much less than the benefit of finding a serious illness early, so the scan is worth doing, as long as it is only used when needed.

Level 3 (5 to 6 marks): benefits and risks both explained, the data used, and a conclusion that follows from them.

Level 2 (3 to 4 marks): benefits and risks given with some explanation, or a conclusion with limited support.

Level 1 (1 to 2 marks): a benefit or a risk given, with little explanation.

Don’t lose marks

- Saying a tracer should emit alpha. Alpha would not leave the body and is strongly ionising, so it would damage cells.

- Saying a tracer should have a long half-life 'so it lasts longer'. The patient would stay radioactive for too long.
- In 'evaluate' questions, giving only benefits or only risks, or giving no conclusion.
- Saying external radiotherapy makes the patient radioactive. The patient is irradiated, not contaminated.

More tips

Memory tricks

- Tracer checklist: **G**amma + **S**hort half-life ('GS: Get Scanned').
- Radiotherapy: aim from many angles, all meeting at the tumour.
- Evaluate = benefits + risks + data + a justified conclusion.

Exam technique

- In a 6-mark evaluation, use the numbers given, e.g. compare the dose with the yearly background dose.
- Use the words 'ionising', 'damages cells' and 'half-life' in medical-use answers.
- When asked why something is suitable, give each property AND the reason it helps.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4 — **Name two medical uses of nuclear radiation**
Exploring internal organs with tracers; destroying unwanted tissue such as tumours.

Grade 5 — **Describe how a medical tracer is used**
A gamma emitter is swallowed or injected and detected outside the body by a gamma camera.

Grade 6 — **Explain the choice of a tracer isotope**
Gamma, so it leaves the body and is weakly ionising; short half-life, so the dose is small.

Grade 6 — **Describe how radiation destroys a tumour**
Gamma beams aimed at the tumour from several directions, or a source placed in or next to it.

Grade 7 — **Explain why radiotherapy beams come from several directions**
The tumour gets a large dose while each part of the healthy tissue gets a much smaller dose.

Grade 8 — **Evaluate risks and benefits using data**
Compare the dose and its risk with the benefit of diagnosis or treatment, and reach a conclusion.

Free notes, Full packs, practice papers and mock exams at chhetriacademy.com. Written for this site; not taken from past papers. Stuck? 1-to-1 tutoring with a free 30-minute trial lesson.