Different half-lives of radioactive isotopes

4.4.3.2 · Atomic structure · revision notes

Radioactive isotopes have half-lives from fractions of a second to billions of years. You need to explain why the hazard from a radioactive material depends on its half-life, and use half-life to choose a suitable isotope for a job. GCSE Physics only, not in Combined Science.

Key facts

- Half-lives range from fractions of a second to billions of years
- Long half-life → activity falls slowly → hazardous for a long time
- Medical tracer: half-life of a few hours
- Long half-life waste must be stored safely for thousands of years
- Short half-life → activity falls quickly → hazardous for a short time
- Grade 8+ only Same number of nuclei: shorter half-life → higher activity
- Smoke alarm or thickness gauge: half-life of years

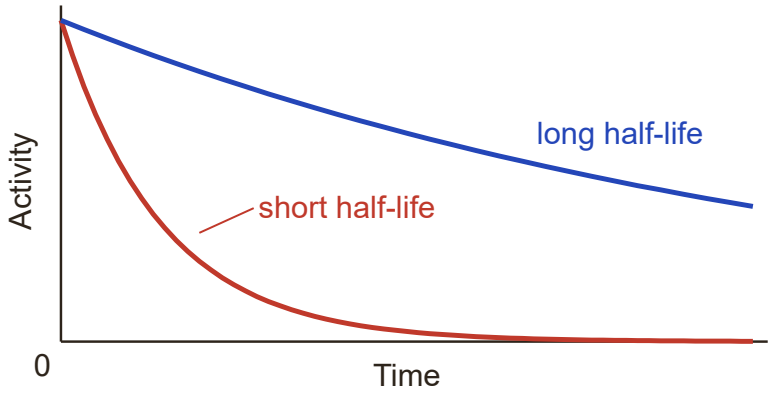
Notes

A very wide range of half-lives

- Different radioactive isotopes have very different half-lives, from fractions of a second to billions of years.
- Examples: technetium-99m about 6 hours; iodine-131 about 8 days; cobalt-60 about 5 years; carbon-14 about 5700 years; uranium-238 about 4.5 billion years.
- Half-lives are often given in standard form, e.g. 4.5×10^9 years. Put them in the same unit, then compare the powers of ten.

How half-life affects the hazard

- **Short half-life**: the activity falls quickly, so the material is only hazardous for a short time (hours or days).
- For the same number of unstable nuclei, the isotope with the shorter half-life has the higher activity, because more nuclei decay each second. So it can be very hazardous at first. Grade 8+ only
- **Long half-life**: the activity falls very slowly, so the material stays hazardous for a very long time. Nuclear waste containing such isotopes must be stored safely for thousands of years.



Same starting activity: the short half-life source is soon safe; the long half-life source stays hazardous.

- The hazard also depends on the type of radiation emitted, and whether the material is inside or outside the body.

Choosing an isotope for a job

- **Medical tracers** need a short half-life (a few hours): long enough to take the images, short enough that the activity in the patient soon falls.
- **Smoke alarms** and **thickness gauges** need a long half-life (years), so the count rate stays nearly constant and the source does not need replacing often.
- When choosing from a table, check the half-life AND the type of radiation.

How to answer each type of question

Explain why the hazard depends on half-life 2 marks Grade 6

1. Link the half-life to how quickly the activity falls.
2. Link that to how long the material stays hazardous.

Example. Some nuclear waste contains isotopes with very long half-lives.
Explain why this waste must be stored safely for thousands of years.

Model answer. A long half-life means the activity falls very slowly (1), so the waste stays radioactive and hazardous for thousands of years (1).

Choose the best isotope from a table

3 marks | Grade 7

1. Decide which type of radiation the job needs.
2. Decide what half-life the job needs.
3. Pick the isotope that has both, and say why the others do not work.

Example. A doctor needs a radioactive tracer. It will be injected into a patient and detected outside the body. The table gives four isotopes the doctor could use.

Isotope	Radiation emitted	Half-life
P	gamma	6 hours
Q	alpha	5 hours
R	gamma	30 years
S	beta	8 days

Which isotope should the doctor use? Explain your answer.

Model answer. Isotope P. Gamma rays pass out of the body, so they can be detected outside it (1). A half-life of 6 hours is long enough to carry out the scan (1), but the activity falls quickly, so the patient's dose is small (1). (Q's alpha and S's beta would be absorbed inside the body; R would stay active in the patient for years.)

Compare the hazards of two isotopes

3 marks | Grade 8

1. Compare the activities at the start.
2. Compare how long each stays hazardous.
3. Say which is the short-term hazard and which is the long-term hazard.

Example. Two samples contain the same number of radioactive nuclei. Sample X has a half-life of 2 days. Sample Y has a half-life of 200 years.
Compare the hazards from the two samples.

Model answer. X has a much higher activity at first, because its nuclei decay much faster (1), so X is more hazardous in the short term (1). Within a few months X has almost all decayed, but Y keeps nearly the same activity for hundreds of years, so Y is the long-term hazard (1).

Don’t lose marks

- Saying a long half-life isotope is more dangerous in every way. For the same number of nuclei its activity is lower; the problem is that it lasts.
- Choosing a medical tracer with a long half-life (the patient would stay radioactive) or an alpha emitter (its radiation would not pass out of the body).
- Using only the half-life, or only the type of radiation, when choosing an isotope from a table.

More tips

Memory tricks

- Short half-life: 'bright but brief'. Long half-life: 'weak but lasting'.
- Tracer half-life: think of a hospital visit, so hours, not years.
- Gauge or alarm half-life: think of the life of the machine, so years.

Exam technique

- In 'choose an isotope' questions, give reasons for your choice and say why the others are unsuitable.
- Quote the half-life from the table in your answer, e.g. '6 hours is long enough to...'.
- For 'explain the hazard', build a chain: half-life → how fast the activity falls → how long it stays dangerous.

What each grade needs

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

Grade 4 — **State that half-lives vary widely**
Half-lives range from fractions of a second to billions of years.

Grade 5 — **Link half-life to how fast activity falls**
A short half-life means the activity falls quickly; a long half-life means it falls slowly.

Grade 6 — **Explain the hazard of long half-lives**
The material stays radioactive for a very long time, so it needs safe long-term storage.

Grade 6 — **Explain the hazard of short half-lives**
The material is hazardous for a short time, as its activity soon falls to a low level.

Grade 7 — **Choose an isotope with a suitable half-life**
E.g. a few hours for a medical tracer; years for a smoke alarm or thickness gauge.

Grade 8 — **Compare activities of samples with different half-lives**
For the same number of nuclei, the isotope with the shorter half-life has the higher activity.

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