

Unstable nuclei, decay and half-life

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Worksheet

Name: _____ Date: _____ Class: _____

These 20 problems train the key ideas of radioactivity: the three types of radiation, nuclear equations, half-life calculations and graphs, fission and fusion, and radiation safety. Data tables, graphs and a dose calculation train you to read real measurements.

Level 1 problems use one idea, level 2 combine two or three steps, and level 3 asks for multi-part reasoning. They suit GCSE, IGCSE, O Level, CBSE Class 9-10 and NGSS high-school physics.

Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS1-8, GCSE P4

Problem 1 Which radiation? (easy)

Nokuthula in Durban sorts facts about nuclear radiation. Name the radiation (alpha, beta or gamma) described by each statement.

1. It is stopped by a sheet of paper.
2. It is a fast-moving electron.
3. It is an electromagnetic wave.
4. It is the most strongly ionising.

Problem 2 Inside a carbon-14 atom (easy)

Carbon-14 has the atomic number 6 and the mass number 14.

1. State the number of protons in a nucleus.
2. Calculate the number of neutrons.
3. State the number of electrons in a neutral atom.
4. Explain why carbon-12 and carbon-14 are called isotopes.

Problem 3 Halving the activity (easy)

A radioactive sample in a school store in Mombasa has an activity of 640 Bq and a half-life of 2.0 days.

1. State the activity after 2.0 days.
2. State the activity after 4.0 days.
3. Calculate the activity after 6.0 days.

Problem 4 Units of radiation (easy)

Convert each measurement.

1. 3.2 kBq into Bq.
2. A half-life of 1.5 days into hours.
3. 0.5 mSv into μ Sv.
4. 45 minutes into hours.

Problem 5 Handling sources safely (easy)

Joaquín in Texas sees a teacher moving a radioactive source with long tongs.

1. State two other safety precautions.
2. Explain why the source is kept in a lead-lined box.
3. State the difference between irradiation and contamination.

Problem 6 Subtracting the background (easy)

Hana in Addis Ababa measures a count rate of 58 counts per minute with a source in place. With the source removed, the count rate is 12 counts per minute.

1. Give two sources of background radiation.
2. Calculate the corrected count rate of the source.
3. Explain why this correction is necessary.

Problem 7 An alpha decay equation (easy)

Polonium-210 has the atomic number 84. It decays by emitting an alpha particle.

1. State the mass number of the new nucleus.
2. State its atomic number.
3. The new element is lead. Write the full name of the product nucleus.

Problem 8 Beta decay equations (medium)

Ming in Beijing studies two beta emitters.

1. Sodium-24 (atomic number 11) emits a beta particle. Give the mass number, atomic number and element name of the new nucleus (magnesium has atomic number 12).
2. Iodine-131 (atomic number 53) emits a beta particle. Give the mass number and atomic number of the new nucleus.
3. Describe what happens inside the nucleus in beta decay.

Problem 9 Half-life from a table (medium)

A student measures the corrected count rate from a sample.

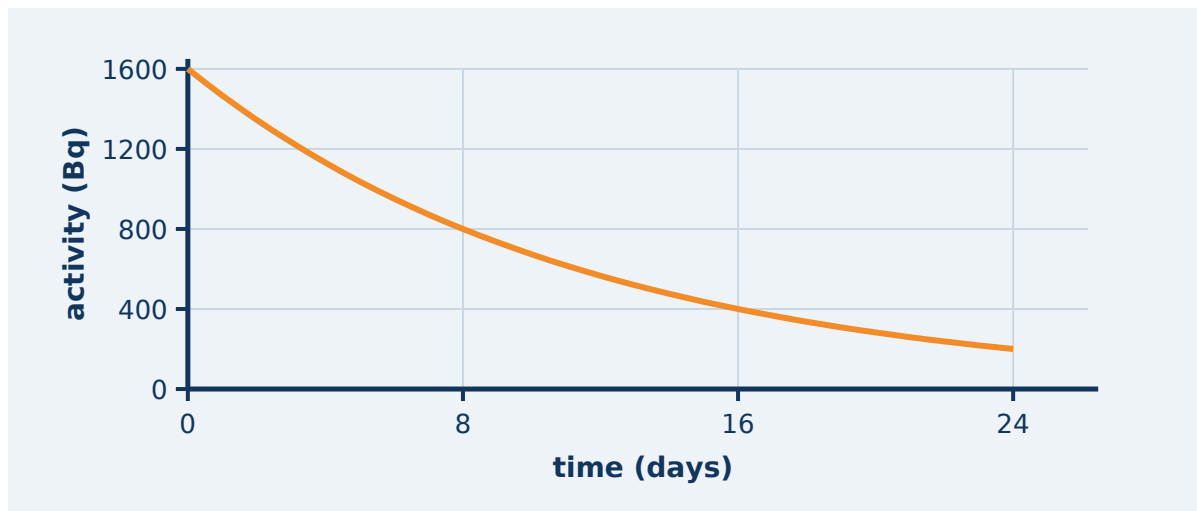
Time (min)	0	10	20	30	40
Counts per minute	800	565	400	283	200

1. Find the half-life.
2. Predict the count rate at 60 minutes.

- Predict the time at which the count rate reaches 50 counts per minute.

Problem 10 Reading a decay graph (medium)

A hospital in Leeds records the activity of an iodine-131 sample.

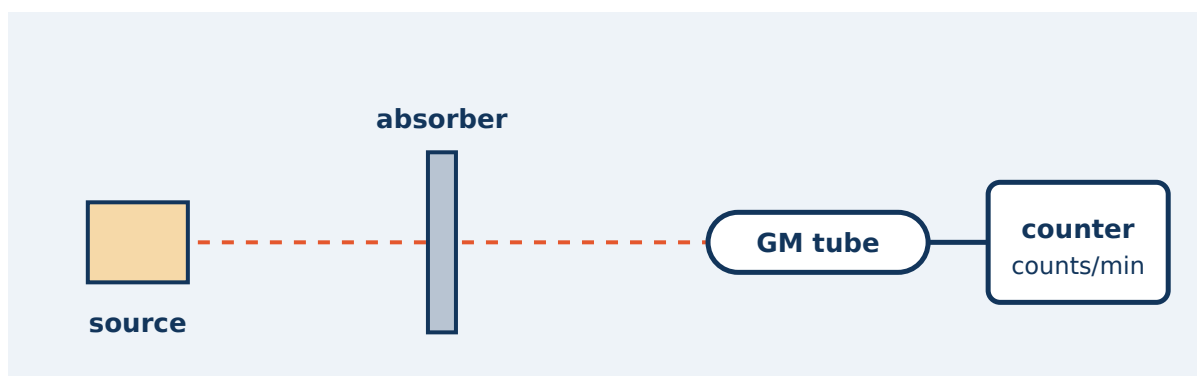


Activity of an iodine sample measured over 24 days.

- Use the graph to find the half-life.
- State the activity after 16 days.
- Estimate the activity after 12 days.
- Explain why the curve never reaches zero.

Problem 11 Which radiation does it emit? (medium)

Diego tests a source with the apparatus shown. The background count rate is 10 counts per minute. Readings: no absorber 410; paper 408; 3 mm aluminium 140; 10 mm lead 12 (all counts per minute).



Testing which radiation a source emits: the absorber is changed and the count rate is read.

- Calculate the corrected count rate for each reading.
- State whether alpha is emitted and give the evidence.
- State which radiations are emitted and explain.

Problem 12 Alpha inside and outside (medium)

A smoke detector contains americium-241, an alpha emitter.

1. Define ionising radiation.
2. Explain why the alpha source is safe in a sealed detector.
3. Explain why it would be very dangerous if swallowed.

Problem 13 Choosing an isotope (medium)

Choose the best source for each job and explain your choice.

1. A medical tracer injected into a patient: gamma emitter with half-life 6 hours, or alpha emitter with half-life 5 years.
2. A smoke detector: alpha emitter with half-life 430 years, or one with half-life 2 days.
3. Explain why a tracer must have a short half-life but a smoke detector a long one.

Problem 14 Balancing fission (medium)

One fission reaction is: neutron + uranium-235 $\rightarrow$ barium-141 + krypton-92 + 3 neutrons.
Barium has atomic number 56 and krypton 36.

1. Show that the mass numbers balance.
2. Show that the atomic numbers balance.
3. Explain what a chain reaction is.
4. State the job of the control rods.

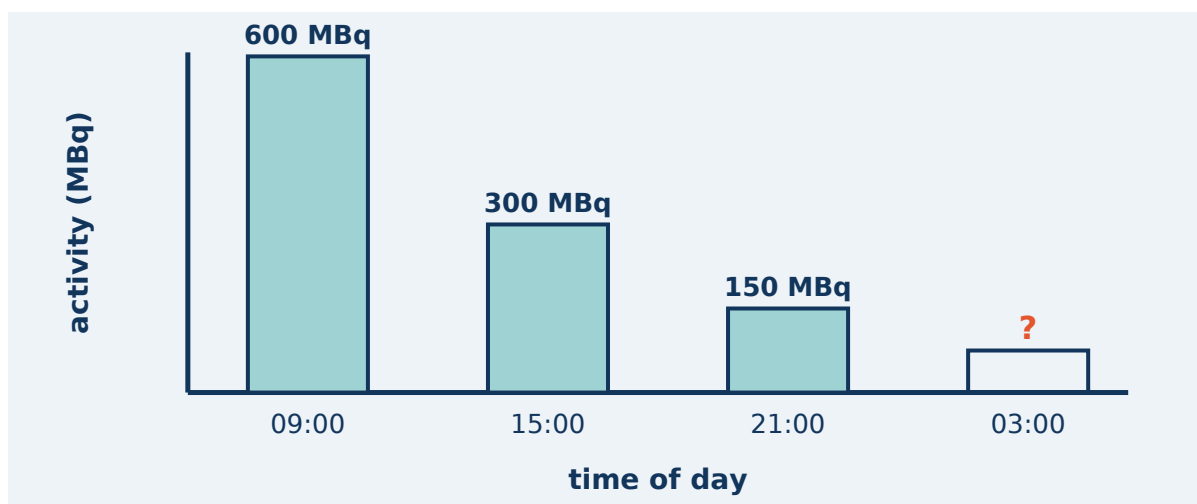
Problem 15 Fission or fusion? (medium)

Compare nuclear fission with nuclear fusion.

1. State the type of nuclei involved in each.
2. State where each process is used or found.
3. Explain why fusion needs a very high temperature.

Problem 16 A hospital dose (hard)

A patient in a hospital is given a dose of technetium-99m with an activity of 600 MBq at 09:00. The half-life is 6.0 hours.



Activity of a technetium-99m dose at 6-hour intervals; the last bar is missing.

1. Calculate the activity at 03:00 on the next day, to complete the bar chart.
2. State the number of half-lives needed for the activity to fall below 10 MBq.
3. Calculate the time at which this happens.
4. Explain why a short half-life is useful for the patient.

Problem 17 Dating an old wooden bowl (hard)

Living wood gives 15.0 counts per minute per gram from carbon-14. A wooden bowl from a museum in Cairo gives 3.75 counts per minute per gram. The half-life of carbon-14 is 5730 years.

1. Calculate the fraction of the original activity that remains.
2. Calculate the number of half-lives that have passed.
3. Calculate the age of the bowl.
4. Another sample shows 7.5 counts per minute per gram. Calculate its age.
5. Suggest one reason why the estimate has an uncertainty.

Problem 18 Spot the errors (hard)

Priya in Chennai wrote three statements. Explain why each is wrong and give the correct statement.

1. "After two half-lives a sample has completely decayed."
2. "In alpha decay the atomic number goes down by 4."
3. "Irradiating a bag of food with gamma rays makes the food radioactive."

Problem 19 Radiographer's dose (hard)

A radiographer in Nairobi works 1800 hours a year in a region where the dose rate is $4.0 \mu\text{Sv}$ per hour. The annual limit for workers is 20 mSv. Each 5 mm of lead halves the dose rate.

1. Calculate the yearly dose in mSv.
2. Calculate it as a percentage of the limit.
3. Calculate the dose rate behind 20 mm of lead.
4. Calculate the new yearly dose in μSv .

5. Suggest two other ways to reduce the dose.

Problem 20 Mass turned into energy (hard)

A reactor produces energy at a steady power of 1.0 GW. Use $E = m c^2$ with $c = 3.0 \times 10^8$ m/s.

1. Calculate the energy released when 1.0 g (1.0×10^{-3} kg) of mass is converted into energy.
2. Calculate how long this energy would supply 1.0 GW (1.0×10^9 W), in seconds.
3. Convert that time into hours.
4. Explain why the mass of the fuel changes only slightly.