

4.4

Atomic structure

Exam-style questions

100 questions • 226 marks

Written in the style of AQA papers, including the required practicals, maths and working scientifically.

How to use this booklet

Answer on paper or in an exercise book — there is no writing space here, so the

booklet can be reused and photocopied cheaply.

Marks are shown in square brackets. Use them to judge how much to write.

Where a graph is to be plotted, a grid is provided.

Use a calculator, a ruler and a pencil for drawing.

Mark your work from the separate answer booklet.

Command words used

State, Give, Name, Write down — a short factual answer, no explanation needed

Describe — say what happens, in order, without needing a reason

Explain — give a reason; 'because', 'so' or 'therefore' should appear

Calculate — show your working and give a unit

Determine — use data given, often from a graph or table

Estimate — an approximate value from reasonable assumptions

Suggest — apply what you know to an unfamiliar situation

Compare — say how things are similar and different, in the same sentence

Evaluate — give both sides, then a conclusion

Design, Plan — set out a method others could follow

Questions are labelled beside the marks where they are Higher Tier only, Separate Physics only, or Working scientifically — the apparatus, variables, accuracy, evaluation and maths skills that carry around a third of the marks in every AQA paper.

4.4.1 Atoms and isotopes

- 1** An atom of lithium is written as ${}^7_3\text{Li}$.
- a State the number of protons, neutrons and electrons in this atom. [3]
 - b Give the relative charges of a proton, a neutron and an electron. [2]
 - c Explain why the atom has no overall charge. [2]
 - d State the approximate radius of an atom and of a nucleus. [2]
 - e The lithium atom loses one electron. Give the charge on the ion formed. [1]
- 2** Carbon has two common isotopes, carbon-12 and carbon-14.
- a Define the term isotope. [2]
 - b State how many neutrons each isotope contains. Carbon has atomic number 6. [2]
 - c Explain why the two isotopes have identical chemical behaviour. [2]
 - d Carbon-14 is radioactive but carbon-12 is not. Suggest why. [1]
- 3** Describe how the model of the atom changed as a result of the alpha scattering experiment.
- a State what the plum pudding model suggested. [2]
 - b Describe the three observations made in the alpha scattering experiment. [3]
 - c Explain what each observation showed about the structure of the atom. [3]
 - d Describe the two further changes to the model after the nuclear model was accepted. [2]
 - e Explain why scientific models are changed over time. Working scientifically [2]

4.4.2 Atoms and nuclear radiation

- 4** A radioactive source emits alpha, beta and gamma radiation.
- a Describe the nature of an alpha particle. [2]
 - b Describe the nature of a beta particle. [2]
 - c Describe the nature of a gamma ray. [1]
 - d Compare the penetrating power of the three radiations. [3]
 - e Compare the ionising power of the three radiations. [2]
 - f Explain why alpha radiation is the most ionising. [2]

5 Complete and explain the following nuclear decays.

- a** Radium-226 (atomic number 88) emits an alpha particle. Give the mass number and atomic number of the nucleus formed. Maths skill [2]
- b** Write the full nuclear equation for this decay. [2]
- c** Carbon-14 (atomic number 6) emits a beta particle. Write the nuclear equation. [2]
- d** State the effect of gamma emission on the mass number and atomic number. [1]
- e** A nucleus emits a neutron. State the effect on the mass number and atomic number. [2]
- f** Explain how you know a nuclear equation is balanced. [2]

6 A student measures the count rate near a radioactive source using a Geiger-Müller tube.

- a** Explain why the student measures the count rate with no source present before starting. Working scientifically [2]
- b** Give two sources of background radiation. [2]
- c** The background count is 25 counts per minute. The detector reads 865 counts per minute beside the source. Calculate the corrected count rate. Maths skill [1]
- d** Explain why the count rate measured varies slightly even when nothing is changed. Working scientifically [2]
- e** Describe two precautions the student should take when handling the source. Working scientifically [2]

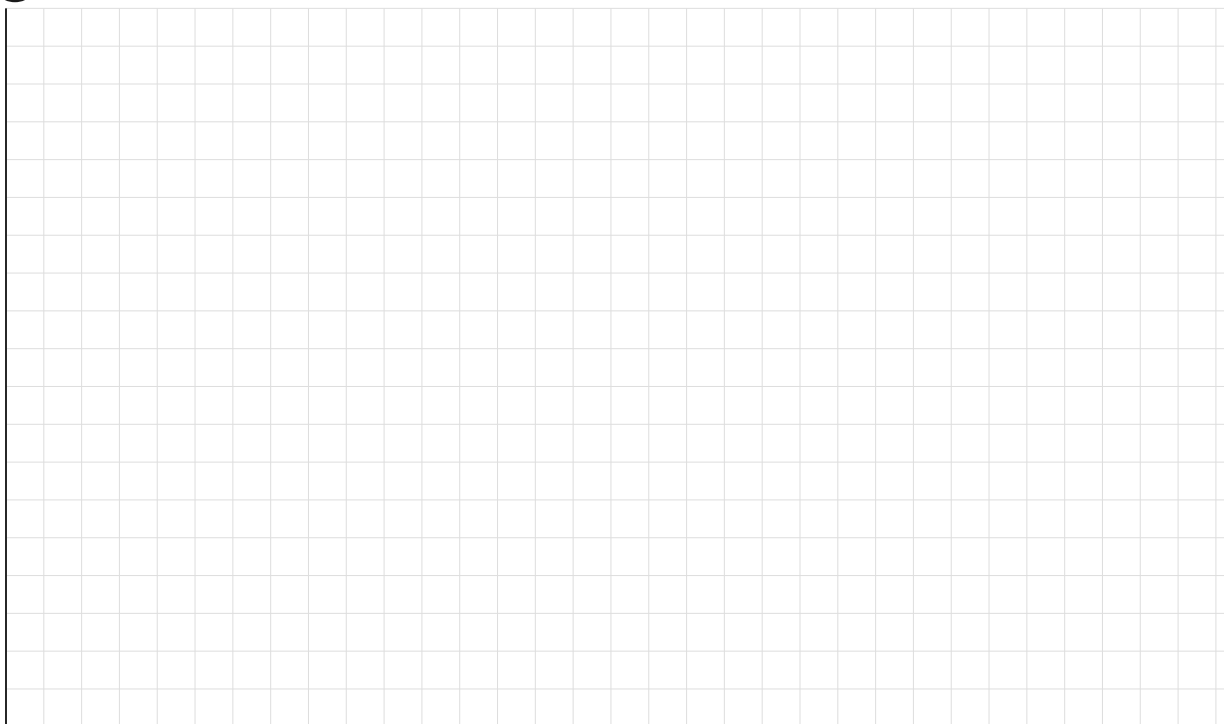
7 A source has a half-life of 6 hours and an initial corrected count rate of 1600 counts per minute.

Time in hours	0	6	12	18	24
Count rate in counts per minute	1600	800	400	200	100

- a** Define the term half-life. [2]
- b** Determine the count rate after 30 hours. Maths skill [2]
- c** Calculate how long it takes for the count rate to fall to one eighth of its initial value. Maths skill [2]
- d** Express the net decline after 24 hours as a ratio. Higher Tier only [2]
- e** Plot a graph of count rate against time on the grid provided, and draw a curve of best fit. Working scientifically [4]
- f** Use your graph to determine the count rate after 9 hours. Working scientifically [2]

8

Use the grid to plot the decay data from the previous question.



No answer is required here — the grid is for your graph.

[0]

9

A sample of a radioactive isotope has an activity of 4800 Bq. After 20 days the activity is 300 Bq.

- a State the unit of activity and what it means. [2]
- b Calculate the half-life of the isotope. Maths skill [3]
- c Predict the activity after a further 15 days. Maths skill [2]
- d Explain why it is impossible to predict when any particular nucleus will decay. [2]

4.4.3 Hazards and uses of radiation

10

A hospital uses radioactive sources for both diagnosis and treatment.

- a Explain the difference between irradiation and contamination. Separate Physics only [3]
- b Explain why contamination is usually more dangerous in the long term. Separate Physics only [2]
- c A medical tracer is a gamma emitter with a short half-life. Explain why both properties are important. Separate Physics only [4]
- d Explain why a source used in radiotherapy to destroy a tumour is used differently from a tracer. Separate Physics only [3]
- e Explain why the findings of studies into the effects of radiation on humans must be published and peer reviewed. Working scientifically · Separate Physics [2]

- 11** A smoke alarm contains a source that emits alpha radiation.
- Explain why an alpha source is suitable for a smoke alarm. Separate Physics only [3]
 - Explain why a gamma source would be unsuitable. Separate Physics only [2]
 - Suggest why a source with a long half-life is used. Separate Physics only [2]
- 12** Describe the problems of disposing of radioactive waste from a nuclear power station, and how the risks are reduced.
- Give your answer. Separate Physics only [4]

4.4.4 Nuclear fission and fusion

- 13** A nuclear power station uses the fission of uranium-235.
- Define nuclear fission. Separate Physics only [2]
 - State what else is released in a fission reaction. Separate Physics only [2]
 - Describe how a chain reaction occurs. Separate Physics only [3]
 - Explain the role of the control rods. Separate Physics only [3]
 - Explain why a reactor is surrounded by thick concrete. Separate Physics only [2]
 - Define nuclear fusion and explain why extreme conditions are needed. Separate Physics only [4]
- 14** Each fission of a uranium-235 nucleus releases 3.2×10^{-11} J of energy.
- Calculate the number of fissions needed each second for a power output of 1.6×10^9 W. Separate Physics · HT only [3]
 - Burning 1 kg of coal releases about 3×10^7 J. Compare this with nuclear fuel. Separate Physics only [3]

Working scientifically

- 15** A student investigates how the count rate from a source changes with the thickness of aluminium placed between the source and the detector.

Thickness in mm	0	1	2	3	4	5
Count rate in counts per minute	720	410	238	140	86	60

- Name the independent and dependent variables. Working scientifically [2]
- State two variables that must be controlled. Working scientifically [2]
- The background count rate is 20 counts per minute. Calculate the corrected count rate at 3 mm. Maths skill [1]
- Describe the pattern shown by the corrected results. Working scientifically [2]
- Deduce which type of radiation the source emits, and justify your answer. Working scientifically [3]
- Explain why each reading is taken over a full minute rather than ten seconds. Working scientifically [2]

- 16** Two students measure the half-life of the same source. Student A obtains 5.8 minutes, 6.1 minutes and 5.9 minutes. Student B obtains 4.9 minutes, 7.2 minutes and 6.0 minutes.
- Calculate the mean of each student's results. Maths skill [2]
 - State which set of results is more precise, and explain why. Working scientifically [2]
 - Explain why repeating the measurement is especially important for radioactive decay. Working scientifically [2]
 - Suggest why neither student can eliminate all variation. Working scientifically [2]
- 17** A newspaper reports: 'Living near a nuclear power station doubles your risk of cancer.' The study was based on 20 people living in one village.
- Give two reasons why this conclusion may not be reliable. Working scientifically [2]
 - Describe how a more reliable study could be designed. Working scientifically [3]
 - Explain why the study should be published in a peer-reviewed journal rather than only in a newspaper. Working scientifically [2]
- 18** The table shows data about four radioactive isotopes.
- | Isotope | Radiation emitted | Half-life |
|---------|-------------------|-------------------|
| A | alpha | 4.5 billion years |
| B | beta | 6 hours |
| C | gamma | 5 days |
| D | alpha | 3 minutes |
- Identify the isotope most suitable as a medical tracer, and justify your answer. Separate Physics only [3]
 - Explain why isotope A is unsuitable for use in a hospital. Separate Physics only [2]
 - Isotope D has a half-life of 3 minutes. Calculate the fraction of the original nuclei remaining after 15 minutes. Maths skill [2]
 - Explain why a source with a very short half-life has a high activity to begin with. [2]
- 19** A student is asked to find out whether a source emits beta or gamma radiation. The student says: 'I will hold a sheet of paper in front of it. If the count rate drops, it is beta.'
- Explain why this method would not work. Working scientifically [2]
 - Describe a method that would work. Working scientifically [3]
 - Explain why the background count rate must be measured and subtracted. Working scientifically [2]
- 20** Uranium-238 decays through a series of steps. In one step, thorium-234 (atomic number 90) emits a beta particle.
- Give the atomic number and mass number of the nucleus formed. Maths skill [2]
 - Explain, in terms of the particles in the nucleus, what happens during beta decay. [2]
 - The nucleus formed then emits an alpha particle. Give the atomic number and mass number of the next nucleus. Maths skill [2]
- 21** A sample of carbon-14 in a piece of ancient wood has an activity of 3.0 counts per minute per gram. Living wood has an activity of 24 counts per minute per gram. The half-life of carbon-14 is 5730 years.
- Calculate the age of the wood. Maths skill [3]
 - State one assumption made in this calculation. Working scientifically [1]
 - Explain why this method is unreliable for very old samples. Working scientifically [2]

- 22** Explain why alpha radiation is the most dangerous type if the source is inside the body, but the least dangerous if the source is outside the body.

Give your answer.

Separate Physics only [4]

- 23** A technician measures the count rate at different distances from a gamma source.

Distance in cm	10	20	30	40	50
Corrected count rate in counts per second	400	100	44	25	16

- a Describe the relationship between count rate and distance. Working scientifically [2]
- b Predict the count rate at 100 cm. Maths skill [2]
- c Explain how this relationship is used as a safety precaution. Working scientifically [2]
- d Suggest why the reading at 30 cm does not fit the pattern exactly. Working scientifically [2]

- 24** Explain what is meant by the activity of a radioactive source, and describe how activity and half-life are related.

- a Define activity and give its unit. [2]
- b Explain why a source with a short half-life has a high initial activity for the same number of nuclei. [2]
- c Explain why the activity of any source decreases with time. [2]

- 25** In 1911 Rutherford's model of the atom replaced the plum pudding model. In 1932 Chadwick discovered the neutron.

- a Explain why the acceptance of a new scientific model usually takes time. Working scientifically [3]
- b Suggest why the discovery of the neutron did not overturn the nuclear model. Working scientifically [2]

- 26** A student says: 'An atom that has lost an electron is called an isotope.'

- a Explain why the student is wrong, and give the correct term. [2]
- b State what happens to the mass number of an atom when it loses an electron. [1]
- c Explain how an atom can become a positive ion. [2]

Extended response

- 27** A school keeps three sealed sources: one alpha, one beta and one gamma emitter.

Describe an investigation to identify which source is which, and explain the safety precautions needed. You should refer to the equipment used and the results you would expect. [6]

- 28** Compare nuclear fission and nuclear fusion as ways of generating electricity.

Your answer should refer to the process, the conditions required, the waste produced and the current practicality of each. [6]