3.5 Atomic Structure: Test Pack

AQA 8461 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

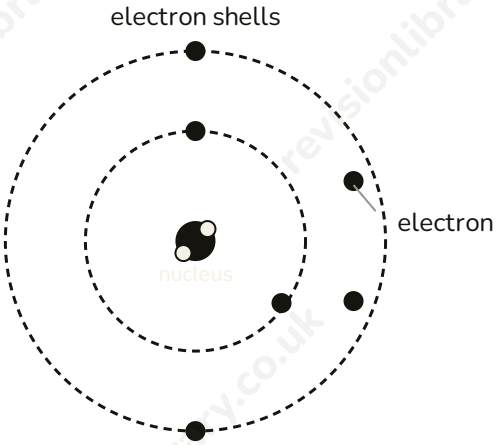
1 An atom is made of protons, neutrons and electrons.

(a) Give the name of the particle that has a negative charge in an atom. **(1)**

(Total for Question 1 is 1 mark)

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2 An atom consists of a small, dense nucleus surrounded by electrons arranged in shells.



(a) State the radius of a typical atom and the radius of a typical nucleus, both in standard form, in metres. **(2)**

(b) Complete the table to give the relative charge of a proton, a neutron and an electron. **(3)**

(c) State the overall charge of a neutral atom and explain why it has this charge. **(2)**

(Total for Question 2 is 7 marks)

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3 Alpha, β and γ radiation differ in penetration and ionising ability.

(a) State which type of radiation is the least penetrating. **(1)**

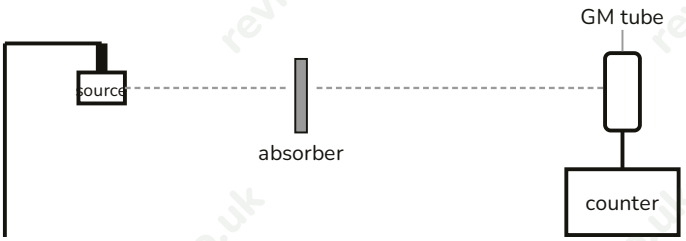
(b) State which type of radiation is the most penetrating. **(1)**

(c) Give one example of a material that will stop β radiation. **(1)**

(Total for Question 3 is 3 marks)

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4 A student carried out the required practical investigation into the absorption of radiation from a radioactive source, using a Geiger-Muller (GM) tube and counter, and sheets of paper, aluminium and lead as absorbers.



Absorber	Corrected count rate (cpm)
None	340
Paper	335
Aluminium (5 mm)	210
Lead (5 cm)	8

(a) State the name of the piece of apparatus used to detect and count the radiation in this experiment. **(1)**

(b) Before starting, the student measured the background count rate for several minutes with no source present. Explain why this step is necessary. **(2)**

(c) Suggest two variables that should be controlled during this investigation to make it a fair test. **(2)**

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(d) The student's results, already corrected for background, are shown below. **(3)**

Absorber: none, corrected count rate = 340 cpm.
Absorber: paper, corrected count rate = 335 cpm.
Absorber: aluminium (5 mm), corrected count rate = 210 cpm.
Absorber: lead (5 cm), corrected count rate = 8 cpm.
Using these results, identify the type(s) of radiation emitted by the source, justifying your answer.

(e) Calculate the percentage of the count rate that is absorbed when the aluminium sheet is added, compared with no absorber. **(2)**

(Total for Question 4 is 10 marks)

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5 A radioactive source that emits α radiation is considered much more hazardous if it is swallowed or inhaled than if it is held outside the body at a safe distance.

(a) Explain why an α-emitting source is more hazardous inside the body but less hazardous outside the body, compared with a γ-emitting source. **(3)**

(b) State one way a radiographer can reduce their own exposure when taking a patient's X-ray image. **(1)**

(Total for Question 5 is 4 marks)

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6 Nuclear equations show how the mass number and atomic number of a nucleus change during radioactive decay. Total mass number and total atomic number must both be conserved (balanced) on each side of the equation.

(a) Americium-241 (241/95 Am) decays by α emission to form neptunium (Np). Determine the mass number and atomic number of the neptunium produced, and write the balanced nuclear equation. **(2)**

(b) Carbon-14 (14/6 C) decays by β emission to form nitrogen (N). Write a balanced nuclear equation for this decay, including mass numbers, atomic numbers and the symbol for a β particle. **(3)**

(Total for Question 6 is 5 marks)

7 A radioactive isotope Z has a half-life of 12 hours. A sample initially has activity 800 counts per minute (cpm).

(a) Calculate the activity after 12 hours. **(1)**

(b) Calculate the activity after 36 hours. **(2)**

(Total for Question 7 is 3 marks)

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8 A plot of activity versus time for a sample of a radioactive isotope shows the activity falling from 1000 cpm to 125 cpm in 24 hours.

(a) Determine the half-life of the isotope. Show your working. **(3)**

(b) State one experimental source of error when measuring activity with a Geiger counter and suggest a way to reduce its effect. **(1)**

(Total for Question 8 is 4 marks)

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9 Consider an element with atomic number 16 (sulfur).

(a) Write the electron arrangement for sulfur in the form of numbers of electrons in each shell. **(1)**

(b) Explain why the first ionisation energy generally increases across Period 3 of the periodic table, using atomic structure ideas. **(3)**

(Total for Question 9 is 4 marks)

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10 A mass spectrometer is used to analyse a pure sample of neon. The instrument shows two peaks at mass/charge values 20 and 22, with relative peak heights proportional to abundance 90 and 10 respectively.

(a) State why two peaks are seen for neon. **(1)**

(b) Calculate the Ar of neon from these peak abundances to two decimal places. **(2)**

(Total for Question 10 is 3 marks)

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Mark scheme · 3.5 Atomic Structure: Test Pack

Question 1

(a) electron cao **B1**

(a) Answer: Electron

Question 2

(a) radius of atom = 1 x 10^{-10} m, oe (allow 10^{-10} m) **B1**

(a) radius of nucleus = 1 x 10^{-14} m (or up to 1 x 10^{-15} m), oe **B1**

(a) Answer: Atom: about 1 x 10^{-10} m. Nucleus: about 1 x 10^{-14} m.

(b) proton = +1 **B1**

(b) neutron = 0 **B1**

(b) electron = -1 **B1**

(b) Answer: Proton = +1, neutron = 0, electron = -1

(c) overall charge = 0 (no charge/neutral) **B1**

(c) because the number of protons (positive) equals the number of electrons (negative), so their charges cancel out, oe **B1**

(c) Answer: Overall charge = 0, because the number of protons equals the number of electrons.

Question 3

(a) α radiation cao **B1**

(a) Answer: Alpha radiation

(b) γ radiation cao **B1**

(b) Answer: Gamma radiation

(c) thin sheet of metal such as aluminium or a few millimetres of aluminium cao **B1**

(c) Answer: A few millimetres of aluminium

Question 4

(a) Geiger-Muller (GM) tube (and counter) **B1**

(a) Answer: A Geiger-Muller (GM) tube connected to a counter.

(b) background radiation is always present and would otherwise be included in (add to) every reading taken with the source **B1**

(b) measuring it separately allows it to be subtracted from later readings, giving the corrected count rate due to the source alone, oe **B1**

(b) Answer: Background radiation would otherwise add to every reading; measuring it first allows it to be subtracted so the count rate due to the source alone is known.

(c) the distance between the source and the GM tube (kept the same for each absorber) **B1**

(c) the time over which each count rate reading is taken (kept the same for each absorber), oe **B1**

(c) Answer: The distance between source and GM tube, and the time each reading is taken over.

(d) the count rate barely changes with paper (340 to 335), so the source emits little or no α radiation **B1**

(d) the count rate falls significantly with aluminium (340 to 210), showing the source emits β radiation, which aluminium mostly absorbs **B1**

(d) the count rate stays high behind the aluminium (210 cpm) but falls to close to zero with lead (8 cpm, near background), showing the radiation that passes through the aluminium is γ radiation, so the source emits β and γ radiation (and no α), oe **B1**

(d) Answer: The source emits β and γ radiation (no α), based on the pattern of absorption: paper has almost no effect, aluminium removes the β radiation, and the radiation that remains is absorbed by lead, so it is γ.

(e) correct method: (340 - 210) / 340 x 100 **M1**

(e) 38.2% (or awrt 38%), cao **A1**

(e) Answer: 38.2% (to 3 s.f.)

Question 5

(a) α radiation is strongly ionising but has a very short range, so outside the body it is easily absorbed by the outer layer of dead skin (or a short distance of air) before reaching living cells, oe **B1**

(a) if swallowed or inhaled, an α source is very close to living cells and all of its (strongly ionising) energy is absorbed by nearby tissue, causing significant damage, oe **B1**

(a) γ radiation is weakly ionising and penetrates the body from outside, so it is comparatively more hazardous than α when the source is external, oe **B1**

(a) Answer: Alpha is strongly ionising but very short-range, so it is stopped before reaching living cells from outside the body, but if swallowed/inhaled all its ionising energy is absorbed by nearby living cells, causing serious damage; γ is weakly ionising but penetrates the body from outside, making it relatively more hazardous externally.

(b) standing behind a lead screen, or leaving the room/standing further away, or wearing a lead apron **B1**

(b) Answer: Standing behind a lead screen (or leaving the room).

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Question 6

(a) mass number of Np = 241 - 4 = 237; atomic number of Np = 95 - 2 = 93 **M1**

(a) correct balanced equation: 241/95 Am -> 237/93 Np + 4/2 He, cao **A1**

(a) Answer: 237/93 Np; equation: 241/95 Am -> 237/93 Np + 4/2 He

(b) correct mass and atomic numbers for nitrogen: mass number stays 14; atomic number increases by 1 to 7 **M1**

(b) correct β particle notation: 0/-1 e **M1**

(b) fully correct balanced equation: 14/6 C -> 14/7 N + 0/-1 e, cao **A1**

(b) Answer: 14/6 C -> 14/7 N + 0/-1 e

Question 7

(a) 400 cpm (activity halved after one half-life) **B1**

(a) Answer: 400 cpm

(b) applies repeated halving: after 36 hours = 800 x $(1/2)^{36/12}$ = 800 x $(1/2)^3$ **M1**

(b) 100 cpm cao **A1**

(b) Answer: 100 cpm

Question 8

(a) recognises number of half-lives: 1000 -> 125 is division by 8 so 3 half-lives in 24 hours **M1**

(a) calculates half-life = 24 / 3 **M1**

(a) gives half-life = 8 hours cao **A1**

(a) Answer: 8 hours

(b) any reasonable source of error and improvement, e.g. background radiation affects counts; subtract background measured separately, oe **B1**

(b) Answer: Background radiation can add counts; measure background activity separately and subtract it from the sample counts.

Question 9

(a) 2, 8, 6 cao **B1**

(a) Answer: 2, 8, 6

(b) states that nuclear charge increases across the period (more protons) or that more attraction on outer electrons **M1**

(b) states that electrons are added to the same shell so shielding does not increase significantly, so net attraction increases **M1**

(b) conclusion: therefore first ionisation energy increases across the period, with reference to atomic structure, oe **A1**

(b) Answer: Because across Period 3 nuclear charge increases (more protons) while electrons enter the same shell so shielding does not rise much; this increases the attraction on the outer electron, so more energy is needed to remove it.

Question 10

(a) because neon has two stable isotopes with different mass numbers (neon-20 and neon-22) oe **B1**

(a) Answer: Neon has two stable isotopes with different mass numbers.

(b) uses weighted average: Ar = (20 x 90 + 22 x 10) / (90 + 10) **M1**

(b) Ar = (1800 + 220) / 100 = 2020 / 100 = 20.20 (to two decimal places) cao **A1**

(b) Answer: 20.20

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