GCSE Topic 4: Atomic Structure Mark Scheme

Q1. Structure of the atom [3]

- Proton (1)
- Neutron (1)
- Electron (1)

Q2. History of the atom [3]

(a) Plum pudding model (1)
(b) Any one feature (1 each, max 2):

- Atom = positive 'pudding' with negative electrons inside
- No nucleus
- Mass spread throughout

Q3. Atomic structure [2]

(a) Proton: +1 (1)
(b) Electron: –1 (1)

Q4. Periodic table [3]

(a) Atomic number = number of protons (1)
(b) Mass number = number of protons + neutrons (1)
Alternative phrasing: total number of particles in nucleus (1)

Q5. Isotopes [4]

(a) Atoms of same element with same number of protons but different number of neutrons (1) (1)
(b)

- Similarity: same number of protons / same element / same chemical properties (1)
- Difference: different number of neutrons / different mass number (1)

Q6. Atoms [3]

(a) Most of the mass in nucleus (1)
(b) Number of protons = number of electrons (1) → charges cancel (1)

Q7. Models of the atom [3]

(a) Rutherford (1)
(b) Any valid conclusion (1 each, max 2):

- Atom mostly empty space
- Nucleus is small and dense
- Nucleus is positively charged

Q8. Nucleus [2]

(a) Neutron relative mass = 1 (1)
(b) Electron relative mass ≈ 0 / very small (1)

Q9. Comparing models [3]

(a) Difference (1 each, max 2):

- Plum pudding: no nucleus; Rutherford: electrons around nucleus
- Rutherford: mass concentrated in nucleus; plum pudding: spread out
(b) Bohr (1)

Q10. Nuclear radiation [3]

- Alpha (1)
- Beta (1)
- Gamma (1)

Q11. Alpha particles [3]

(a) Charge = +2 (1)
(b) 2 protons and 2 neutrons (like a helium nucleus) (1) (1)

Q12. Beta radiation [3]

(a) Charge = –1 (1)
(b) High-speed electron (1) emitted from nucleus (1)

Q13. Comparing radiation [2]

(a) Stopped by paper = alpha (1)
(b) Most penetrating = gamma (1)

Q14. Half-life [4]

(a) Time taken for:

- Activity (count rate) to halve (1) OR
- Half the unstable nuclei to decay (1)
  (b) Any one valid use (1 each, max 2):
- Medical tracers
- Diagnosing or monitoring organ function
- Choosing isotopes that don’t last too long in body

Q15. Uses of radiation [3]

(a) Use of gamma in medicine (1):

- Sterilising equipment
- Imaging / tracers
- Radiotherapy (cancer treatment)
  (b) Precautions (1 each, max 2):
- Use tongs / keep distance
- Use shielding (lead box)
- Minimise exposure time
- Wear protective clothing / monitor dose

Q16. Structure of atoms [3]

(a) Proton: +1 (1)
Neutron: 0 (neutral) (1)
(b) Electrons in shells / energy levels around nucleus (1)

Q17. Isotopes [4]

(a) Isotopes: atoms of same element with same number of protons but different number of neutrons (1) (1)
(b) Same number of electrons (1) → so same chemical reactions / properties (1)

Q18. Development of model [5]

(a) Plum pudding model feature (any 1, max 2):

- Atom is positive ‘pudding’ with electrons inside (1)
- No nucleus (1)
  (b) Gold foil experiment:
- Most particles went through → atom mostly empty space (1)
- Some deflected → nucleus is small and positive (1)

- Led to nuclear model (1)

Q19. Electron arrangements [4]

(a) Sodium electronic structure: 2,8,1 (1 for correct shells, 1 for total = 11)
(b) Both sodium and lithium have 1 electron in outer shell (1) → similar reactions (1)

Q20. Radioactive decay [5]

(a) Alpha, beta, gamma (1 each)
(b) Random because:

- Cannot predict which nucleus will decay (1)
- Cannot predict exactly when decay will happen (1)

Q21. Alpha radiation [3]

(a) 2 protons and 2 neutrons (1)
(b) Large mass/charge → collides strongly with atoms (1) → easily knocks electrons off (1)

Q22. Beta radiation [3]

(a) Inside nucleus: neutron changes to proton + electron (1) electron emitted as beta (1)
(b) Beta particle charge = –1 (1)

Q23. Gamma radiation [3]

(a) Electromagnetic wave / photon released (1)
(b) No mass or charge (1) → passes through atoms without much interaction (1)

Q24. Absorption of radiation [5]

(a) Stopped by paper = alpha (1)
(b) Most penetrating = gamma (1)
(c) Uses (1 each, max 3):

- Alpha → smoke detectors
- Beta → thickness control (paper/metal foil) or medical tracers
- Gamma → sterilising equipment, imaging, treating cancer

Q25. Ionising radiation [3]

- Radiation knocks electrons off atoms (1)
- Forms ions (1)
- Can damage DNA/cells, leading to cancer or cell death (1)

Q26. Half-life [4]

(a) Time for half nuclei to decay (1) or activity/count rate to halve (1)
(b) Medical use:

- Choose isotope with suitable half-life → lasts long enough for test but not for long in body (1) (1)

Q27. Background radiation [3]

(a) Natural sources (1 each, max 2):

- Radon gas
- Rocks/buildings
- Cosmic rays
  (b) Man-made source: medical (X-rays, radiotherapy), nuclear industry, weapons testing (1)

Q28. Dangers of radiation [3]

(a) Short-term: sickness, burns, cell damage (1)
(b) Long-term: cancer, genetic mutations (1)
(c) Precaution: shielding, minimise exposure time, distance, monitoring dose (1)

Q29. Tracers [3]

(a) Property: emits radiation that can be detected outside body / short half-life (1)
(b) Advantage: diagnoses problems inside body non-invasively (1)
Disadvantage: exposure to radiation / possible harm (1)

Q30. Nuclear equations [2]

Uranium-238 → Thorium-234 + alpha
Equation:
$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$ (1 for numbers correct, 1 for symbols correct)

Q31. Nuclear fission [5]

(a) Fission = splitting of a large nucleus into smaller nuclei (1) releasing energy (1)
(b) Uranium-235 absorbs neutron (1) → splits into 2 smaller nuclei + 2 or 3 neutrons (1) → releases energy (1)

Q32. Chain reactions [4]

(a) Neutrons from one fission event cause further fissions (1) → self-sustaining process (1)
(b) Control rods absorb neutrons (1) → stop reaction from running too fast/exploding (1)

Q33. Fusion [3]

(a) Fusion = joining of small nuclei to form larger nucleus (1)
(b) High temperatures needed: nuclei repel (electrostatic repulsion) (1) → need high energy to overcome (1)

Q34. Compare fission and fusion [2]

Similarity: both release energy (1)
Difference: fission = splitting heavy nuclei; fusion = joining light nuclei (1)

Q35. Nuclear power evaluation [6]

Indicative content:

- Benefits: reliable supply, low greenhouse gas emissions, high energy yield (1–3)
- Risks: accidents (radiation release), radioactive waste disposal, high cost (1–3)
  Levelled marking:
- 1–2 marks: simple statements (e.g. “gives energy but dangerous”)
- 3–4 marks: some detail of both risks and benefits
- 5–6 marks: balanced argument with clear evaluation

Q36. Radioactive decay [3]

Half-life = 3 h
After 9 h → 3 half-lives → activity = 800 ÷ 2 ÷ 2 ÷ 2 = 100 Bq
Marks:

- Correct method (halving each time) (1)
- 3 half-lives recognised (1)
- Final answer = 100 Bq (1)

Q37. Nuclear accidents [2]

- Release of radioactive material contaminating land/water (1)
- Long-term effects on ecosystems/food chain (1)

Q38. Nuclear medicine [2]

Short half-life isotopes:

- Decay quickly → radiation doesn't stay in body long (1)
- Reduces long-term risk (1)

Q39. Nuclear reactions [3]

(a) Sun powered by nuclear fusion (1)
(b) Fusion reactors:

- Produce lots of energy (1)
- No long-lived radioactive waste / fuel readily available (1)

Q40. Radioactive waste [2]

Problem:

- Highly radioactive for thousands of years (1)
- Must be stored securely (deep underground / prevent leaks) (1)

Q41. Atomic structure [4]

(a) Radius of atom ≈ **1×10^{-10} m** (1)
(b) Radius of nucleus ≈ **1×10^{-14} m** (1)
(c)

- Electrons are very far from nucleus compared to their size (1)
- So most of atom is empty space (1)

Q42. Ionisation [5]

(a)

- Ionising radiation knocks out electrons from atoms (1)
- Leaving positively charged ions (1)
  (b)
- Alpha = **most ionising** (1)
- Beta = **moderately ionising** (1)
- Gamma = **least ionising** (1)

Q43. Nuclear equations [2]

Carbon-14 beta decay:
$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e$

- Correct numbers (1)
- Correct symbols (1)

Q44. Activity [4]

(a) Activity = number of decays per second (1)
(b) Unit = **Becquerel (Bq)** (1)
(c)

- Activity decreases over time (1)
- Because fewer unstable nuclei remain (1)

Q45. Dose [4]

(a) Absorbed dose = energy absorbed per unit mass (1)
(b) Unit of dose equivalent = **Sievert (Sv)** (1)
(c)

- Different radiation types cause different biological effects (1)

- Dose equivalent takes this into account (1)

Q46. Irradiation vs contamination [4]

(a) Irradiation = exposure to radiation from a source (1)
(b) Contamination = radioactive material deposited inside/outside body (1)
(c) Contamination more dangerous:

- Source stays inside/near body (1) → continues to irradiate tissue (1)

Q47. Alpha inside vs outside [3]

- Inside body: alpha particles strongly ionising (1)
- Cause lots of damage in short distance (1)
- Outside body: stopped by skin/air (1)

Q48. Radiation monitoring [2]

Method:

- Film badge (darkens when exposed) (1)
- Or dosimeter (digital reading of dose) (1)

Q49. Nuclear fission [3]

(a)

- Fission products have kinetic energy (1)
- Energy transferred to thermal energy of coolant/water → drive turbines (1)
 (b) Transfer method: conduction, convection, or radiation (1)

Q50. Chain reactions [4]

(a)

- Control rods absorb excess neutrons (1)
- So only one neutron per fission continues chain (1)
 (b)
- Uncontrolled = too many neutrons (1) → energy release leads to explosion (1)

Q51. Fusion [3]

(a) Advantage:

- No long-lived radioactive waste / fuel abundant (1)
 (b)
- Nuclei repel each other (electrostatic repulsion) (1)
- Requires very high temperatures/pressures to overcome (1)

Q52. Beta thickness monitoring [3]

- Beta source directed at material (1)
- Detector on other side measures count rate (1)
- If material too thick → less beta passes through; system adjusts rollers (1)

Q53. Background radiation [3]

(a) Factor: location, altitude, rocks, radon gas, medical use (any 1) (1)
 (b)

- Radon is radioactive (1)

- Emits ionising radiation → increases dose (1)

Q54. Carbon-14 dating [3]

- Living things take in carbon-14 (1)
- After death no new carbon-14 taken in (1)
- Measure remaining carbon-14 vs half-life to calculate age (1)

Q55. Nuclear energy evaluation [6]

Indicative content:
Advantages:

- Reliable base-load electricity (1)
- Low CO_2 emissions → reduces climate change (1)
- High energy output (1)

Disadvantages:

- Radioactive waste disposal issues (1)
- Risk of accidents / disasters (1)
- High cost of building/decommissioning (1)

Level descriptors:

- 1–2 marks: basic points, one-sided
- 3–4 marks: some balance, limited detail
- 5–6 marks: detailed, balanced discussion with clear evaluation