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HIGHER

P4H Atomic Structure: Higher Tier Practice

AQA 8463 · Calculator allowed · about 85 minutes

Total Marks

Name: ______________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 An atom of element X has 17 protons and 20 neutrons.

(a) State the atomic number of element X. **(1)**

(b) Write the nuclide notation for this atom, in the form A X, where A is the mass number and X is the element symbol. Use X as the element symbol. **(1)**

....

(Total for Question 1 is 2 marks)

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2 Two isotopes of element Y are 23Y and 25Y. A sample contains 75 atoms of 23Y and 25 atoms of 25Y.

(a) Calculate the relative atomic mass (Ar) of element Y to one decimal place using this sample. **(3)**

....

(Total for Question 2 is 3 marks)

3 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 3 is 3 marks)

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4 The atomic model changed in the early 20th century as evidence accumulated. A student lists three pieces of evidence: α scattering, line spectra, and charge-to-mass ratio measurements of the electron.

(a) Explain how α scattering provided evidence for a small dense nucleus. **(2)**

(b) Briefly state what line spectra indicate about electron energy levels. **(1)**

(c) State what the measurement of the charge-to-mass ratio of the electron showed about subatomic particles. **(1)**

(Total for Question 4 is 4 marks)

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5 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 5 is 3 marks)

6 Write nuclear equations for the following decay processes. Use element symbols and mass and atomic numbers where appropriate.

(a) 210Po undergoes α decay. Write the nuclear equation. **(2)**

(b) 14C decays by β minus emission. Write the nuclear equation. **(2)**

(Total for Question 6 is 4 marks)

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7 A mass spectrum of an element Q shows three isotopic peaks at masses 10, 11 and 12 with relative abundances 20, 70 and 10 respectively.

(a) Calculate the relative atomic mass (Ar) of element Q to two decimal places. **(3)**

....

(Total for Question 7 is 3 marks)

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8 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 8 is 4 marks)

9 An electron in an atom moves between two energy levels. The energy difference between the levels is 2.55×10^{-19} J. Use Planck constant $h = 6.63 \times 10^{-34}$ J s and speed of light $c = 3.00 \times 10^{8}$ m s^{-1}.

(a) Calculate the wavelength of the photon emitted when the electron drops between these levels. Give your answer in nanometres to three significant figures. **(3)**

....

(Total for Question 9 is 3 marks)

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10 In a scattering experiment, 1000 α particles are directed at a thin metal foil. The observed counts are: 980 passed straight through with negligible deflection, 15 suffered small angle deflections, and 5 were deflected through angles greater than 90 degrees.

(a) Using these results, explain what this tells you about the structure of the atom. Make two clear points, one about the space inside the atom and one about the nucleus. **(3)**

(Total for Question 10 is 3 marks)

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11 Explain how atomic models developed from J J Thomson's plum pudding model to Rutherford's nuclear model and then to Bohr's model that included quantised electron energy levels. In your answer include the experimental evidence that led to each change and how each model addressed problems with the previous model.

(Total for Question 11 is 6 marks)

12 An element R has two isotopes with masses 39.010 u and 41.014 u and natural abundances 93.26% and 6.74% respectively. Calculate the relative atomic mass (Ar) of R to three significant figures. Use the abundances as given.

(a) Calculate Ar to three significant figures. **(4)**

....

(Total for Question 12 is 4 marks)

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13 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 13 is 4 marks)

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14 A sealed source emits γ radiation. The counting rate measured behind 3 cm of lead is 250 counts per minute. The half-value layer (HVL) for this γ energy in lead is 1.5 cm.

(a) Calculate the counting rate that would be measured with no lead shielding present. Assume only attenuation by the lead affects the rate and use the HVL relationship. **(3)**

....

(b) Give one safety precaution for working with γ sources in the laboratory. **(1)**

(Total for Question 14 is 4 marks)

15 A sample of an unknown element shows the following atomic behaviour: it forms a stable 2+ ion by losing two electrons, it has four occupied electron shells, and its mass number is close to 40. Use this information to suggest the most likely element and justify your answer with three points based on atomic structure.

(a) Name the most likely element and give three atomic structure reasons that support your choice. **(4)**

(Total for Question 15 is 4 marks)

Mark scheme · P4H Atomic Structure: Higher Tier Practice

Question 1

- (a) **B1** 17 (number of protons cao)
- **(a) Answer: 17**
- (b) **B1** 37 X (mass number = 17 + 20 = 37) cao
- **(b) Answer: 37 X**

Question 2

- (a) **M1** uses weighted average method: Ar = (23 x 75 + 25 x 25) / (75 + 25)
- (a) **A1** calculates weighted sum: 23 x 75 = 1725 and 25 x 25 = 625
- (a) **A1** Ar = (1725 + 625) / 100 = 2350 / 100 = 23.5 (to one decimal place) cao
- **(a) Answer: 23.5**

Question 3

- (a) **B1** because neon has two stable isotopes with different mass numbers (neon-20 and neon-22) oe
- **(a) Answer: Neon has two stable isotopes with different mass numbers.**
- (b) **M1** uses weighted average: Ar = (20 x 90 + 22 x 10) / (90 + 10)
- (b) **A1** Ar = (1800 + 220) / 100 = 2020 / 100 = 20.20 (to two decimal places) cao
- **(b) Answer: 20.20**

Question 4

- (a) **M1** states that most α particles passed through the foil but some were deflected at large angles
- (a) **A1** concludes that most of atom is empty space but there is a small, dense, positively charged nucleus that caused large deflections, oe
- **(a) Answer: Most α particles passed through indicating mostly empty space; occasional large deflections showed a small dense positive nucleus that repelled some alphas.**
- (b) **B1** that electrons occupy discrete energy levels and emit/absorb photons when moving between levels, oe
- **(b) Answer: Electrons occupy discrete energy levels and emit or absorb photons when changing levels.**
- (c) **B1** that electrons are very small, negatively charged particles with a large charge-to-mass ratio, showing atoms have smaller charged parts, oe
- **(c) Answer: That electrons are very small, negatively charged particles with a large charge-to-mass ratio, showing atoms have smaller charged parts.**

Question 5

- (a) **B1** 400 cpm (activity halved after one half-life)
- **(a) Answer: 400 cpm**
- (b) **M1** applies repeated halving: after 36 hours = 800 x $(1/2)^{36/12}$ = 800 x $(1/2)^3$
- (b) **A1** 100 cpm cao
- **(b) Answer: 100 cpm**

Question 6

- (a) **M1** shows α particle as 4He (mass 4, atomic 2) and subtracts from parent: 210 -> 206 and atomic number subtracts by 2
- (a) **A1** 210Po -> 206Pb + 4He (or 210 84 Po -> 206 82 Pb + 4 2 He) cao
- **(a) Answer: 210 84 Po -> 206 82 Pb + 4 2 He**
- (b) **M1** shows β minus as electron with mass 0 and charge -1 and adjusts atomic number +1
- (b) **A1** 14 6 C -> 14 7 N + 0 -1 e (or 14C -> 14N + β) cao
- **(b) Answer: 14 6 C -> 14 7 N + 0 -1 e**

Question 7

- (a) **M1** uses weighted average: Ar = (10 x 20 + 11 x 70 + 12 x 10) / 100
- (a) **A1** calculates weighted sum: 200 + 770 + 120 = 1090
- (a) **A1** Ar = 1090 / 100 = 10.90 (to two decimal places) cao
- **(a) Answer: 10.90**

Question 8

- (a) **B1** 2, 8, 6 cao
- **(a) Answer: 2, 8, 6**
- (b) **M1** states that nuclear charge increases across the period (more protons) or that more attraction on outer electrons
- (b) **M1** states that electrons are added to the same shell so shielding does not increase significantly, so net attraction increases
- (b) **A1** conclusion: therefore first ionisation energy increases across the period, with reference to atomic structure, oe
- **(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 9

- (a) **M1** substitutes into λ = h c / E
- (a) **A1** calculates λ = (6.63e-34 x 3.00e8) / 2.55e-19 = 7.80e-7 m
- (a) **A1** converts to nm: 7.80e-7 m = 780 nm, gives 780 nm cao
- **(a) Answer: 780 nm**

Question 10

- (a) **M1** point about most particles passing through indicating atoms are mostly empty space
- (a) **M1** point about some particles deflected indicating a small dense region
- (a) **A1** explicit conclusion that the small dense region is positively charged nucleus which causes strong deflections, oe
- **(a) Answer: Most α particles pass through, showing atoms are mostly empty space; occasional large deflections show a small, dense, positively charged nucleus that repels α particles.**

Question 11

- **Level 3** (5-6): Detailed explanation. Candidate describes the plum pudding, Rutherford and Bohr models; explains the key experimental evidence (e.g. alpha scattering, line spectra) and links how each new model solved shortcomings of the previous model. Clear, accurate use of atomic structure vocabulary.
- **Level 2** (3-4): Developing explanation. Candidate describes two models and gives some correct experimental evidence and explanation of why the change was needed. Some links to atomic structure vocabulary.
- **Level 1** (1-2): Basic statement(s). Candidate gives limited description of a model or single piece of evidence with minimal explanation.
- **Indicative content:**
  - Plum pudding model: electrons embedded in a diffuse positive charge; could not explain large angle deflections.
  - Rutherford alpha scattering: most alpha passed through but some deflected strongly, implying small dense positive nucleus; Rutherford model had nucleus and mostly empty space but could not explain electron stability or line spectra.
  - Bohr model: introduced discrete electron energy levels to explain atomic line spectra and stability; electrons occupy quantised orbits and emit/absorb photons when transitioning between levels.
  - Link each experimental result to the model change and explain how the later model resolved the specific problem of the earlier model.

Question 12

- (a) **M1** uses weighted average: Ar = (39.010 x 93.26 + 41.014 x 6.74) / 100
- (a) **M1** calculates weighted contributions: 39.010 x 93.26 and 41.014 x 6.74
- (a) **A1** adds contributions and divides by 100 to find Ar
- (a) **A1** gives Ar = 39.1 to three significant figures cao
- **(a) Answer: 39.1**

Question 13

- (a) **M1** recognises number of half-lives: 1000 -> 125 is division by 8 so 3 half-lives in 24 hours
- (a) **M1** calculates half-life = 24 / 3
- (a) **A1** gives half-life = 8 hours cao
- **(a) Answer: 8 hours**
- (b) **B1** any reasonable source of error and improvement, e.g. background radiation affects counts; subtract background measured separately, oe
- **(b) Answer: Background radiation can add counts; measure background activity separately and subtract it from the sample counts.**

Question 14

- (a) **M1** uses attenuation relation: rate_shielded = rate_unshielded x $(1/2)^{\text{thickness / HVL}}$ and rearranges for rate_unshielded
- (a) **M1** substitutes thickness 3 cm and HVL 1.5 cm to get $(1/2)^{3/1.5} = (1/2)^2 = 1/4$
- (a) **A1** calculates unshielded rate = 250 x 4 = 1000 cpm cao
- **(a) Answer: 1000 cpm**
- (b) **B1** example: use suitable shielding, minimise time near source, keep distance from source, or use remote handling tools, oe
- **(b) Answer: Use suitable shielding and minimise time spent near the source; for example, handle the source with tongs and stand behind a lead barrier.**

Question 15

- (a) **M1** identifies calcium as the likely element (mass close to 40 and forms 2+ ions)
- (a) **M1** states that calcium's electron configuration is 2,8,8,2, giving four occupied electron shells, matching the clue given
- (a) **A1** gives justification that Ca commonly forms a 2+ ion by losing its two outer electrons to achieve a stable, full-shell (noble gas) electron configuration
- (a) **A1** relates mass number close to 40 to calcium-40 being by far the most abundant isotope, oe
- **(a) Answer: Calcium. Its electron configuration is 2,8,8,2, giving four occupied electron shells; it commonly forms a 2+ ion by losing its two outer electrons to achieve a stable, full-shell configuration; and its most abundant isotope, calcium-40, gives it a mass number close to 40.**