2.1 Atomic Structure and the Periodic Table: 1-hour Pack

AQA 8462 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 The table shows some information about three elements: A, B and C.

Element	Atomic number	Mass number
A	3	7
B	8	16
C	11	23

(a) For element A, state the number of protons and the number of neutrons. **(2)**

(Total for Question 1 is 2 marks)

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2 Mixtures can be separated using physical methods.

(a) Name the method used to obtain pure water from a solution of salt in water. **(1)**

(b) Name the method used to separate an insoluble solid from a liquid. **(1)**

(c) A student separates a mixture of coloured dyes using paper chromatography. Name the stationary phase and the mobile phase in this method. **(2)**

(Total for Question 2 is 4 marks)

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3 Atoms are made of protons, neutrons and electrons.

(a) Give the relative charge of a proton and the relative charge of an electron. **(2)**

(b) The relative mass of a proton is 1. State the relative mass of an electron. **(1)**

(c) Where in the atom is almost all of the mass concentrated? **(1)**

(Total for Question 3 is 4 marks)

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4 A sample of chlorine gas contains 75% chlorine-35 atoms and 25% chlorine-37 atoms.

(a) Calculate the relative atomic mass of chlorine in this sample. Give your answer to 1 decimal place. **(2)**

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(Total for Question 4 is 2 marks)

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5 Electrons are arranged in energy levels (shells) around the nucleus.

(a) An atom of chlorine has 17 electrons. Write the electronic structure of this atom. **(1)**

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(b) An atom has the electronic structure 2,8,8,2. State its atomic number. **(1)**

(c) State what the number of electrons in the outer shell of an atom tells you about the atom's position in the periodic table. **(1)**

(Total for Question 5 is 3 marks)

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6 Some atoms have isotopes. Isotopes of the same element have the same number of protons but different numbers of neutrons.

(a) Define the term isotope. **(1)**

(b) Explain one reason why isotopes of an element have nearly identical chemical behaviour. **(2)**

(Total for Question 6 is 3 marks)

7 The periodic table groups elements with similar properties. Predict the property and give a reason.

(a) Predict whether elements in Group 0 (noble gases) have high or low boiling points compared with Group 1 metals, and give one reason. **(4)**

(Total for Question 7 is 4 marks)

8 Explain how the periodic table provides evidence for the existence of atomic structure and patterns in elements. In your answer include how properties change across a period and down a group, and refer to electron arrangement.

(Total for Question 8 is 6 marks)

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9 State the electron shell arrangement for phosphorus (atomic number 15) using shell notation (for example, 2,8,5) and explain, using this arrangement, why phosphorus typically forms three covalent bonds in molecules such as PCl_3, and state which group of the periodic table phosphorus is in.

(Total for Question 9 is 4 marks)

10 An unknown ionic compound contains elements A and B. Element A forms A2+ ions and element B forms B3- ions. The empirical formula of the compound is A3B2. Explain why this is the correct empirical formula.

(Total for Question 10 is 4 marks)

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11 Chlorine is in Group 7. Predict and explain what happens when potassium iodide solution is mixed with chlorine water.

(Total for Question 11 is 4 marks)

12 A student reports reacting an unknown metal M with excess dilute hydrochloric acid: M + 2HCl -> MCl2 + H_2. A sample of 0.327 g of the metal reacts completely with the acid. Analysis of the resulting solution shows it contains 0.3545 g of chloride ions (Cl^-). Calculate the total amount of chloride ions, then use the excess acid condition to deduce bounds on the amount and relative atomic mass of M. Assess whether any of the candidates below is consistent with the reported conditions, and explain whether a unique relative atomic mass can be determined. (Ar of Cl = 35.45.) Candidates: Mg (24.3), Al (27.0), Fe (55.8), Zn (65.4). Show all your working.

(Total for Question 12 is 7 marks)

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Mark scheme · 2.1 Atomic Structure and the Periodic Table: 1-hour Pack

Question 1

(a) protons = atomic number = 3 **B1**

(a) neutrons = mass number - atomic number = 7 - 3 = 4 **B1**

(a) Answer: Protons 3; Neutrons 4

Question 2

(a) (simple) distillation **B1**

(a) Answer: Distillation

(b) filtration **B1**

(b) Answer: Filtration

(c) stationary phase = the (chromatography) paper **B1**

(c) mobile phase = the solvent (e.g. water) **B1**

(c) Answer: Stationary phase: the paper; mobile phase: the solvent

Question 3

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

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

(a) Answer: Proton +1; electron -1

(b) very small / negligible / 1/1836 (allow: almost 0) **B1**

(b) Answer: Very small (negligible, about 1/1836)

(c) (in) the nucleus **B1**

(c) Answer: The nucleus

Question 4

(a) (75 x 35 + 25 x 37) / 100 (oe) **M1**

(a) 35.5 cao **A1**

(a) Answer: 35.5

Question 5

(a) 2,8,7 **B1**

(a) Answer: 2,8,7

(b) 20 **B1**

(b) Answer: 20

(c) it equals the group number (of the element) **B1**

(c) Answer: It equals the group number

Question 6

(a) atoms of the same element with the same number of protons but different numbers of neutrons cao **B1**

(a) Answer: Atoms of the same element with the same number of protons but different numbers of neutrons

(b) states that chemical behaviour depends on electrons and electron arrangement **M1**

(b) since isotopes have the same number of electrons they behave similarly chemically cao **A1**

(b) Answer: Chemical behaviour depends on electron arrangement; isotopes have the same electrons so behave similarly

Question 7

(a) states that noble gases have lower boiling points than Group 1 metals **M1**

(a) gives reason: noble gases are monatomic (single atoms) with weak forces between their atoms (intermolecular or London forces), oe **M1**

(a) Group 1 metals have strong metallic bonds between their atoms, oe **A1**

(a) so less energy is needed to overcome the forces between noble gas atoms than to break metallic bonds, giving a lower boiling point, oe **A1**

(a) Answer: Noble gases have lower boiling points because they are monatomic with weak intermolecular forces, whereas metals have strong metallic bonds requiring more energy

Question 8

Level 3 Detailed explanation linking periodic table patterns to atomic structure. Describes change across a period (e.g. increasing proton number and electrons filling same shell leading to changes in properties such as metallic to non-metallic behaviour, change in reactivity) and change down a group (e.g. more shells, outer electron further from nucleus, trends in reactivity). Refers to electron arrangement and gives at least two linked examples or clear reasoning. **5-6**

Level 2 Reasonable explanation with some link to electron arrangement. Describes either across-period or down-group trend correctly and gives limited explanation using electrons. May have one clear example. **3-4**

Level 1 Basic statements about the periodic table or atomic structure. May state that elements are arranged by atomic number or that elements in groups have similar properties, without linking to electron arrangement or giving clear examples. **1-2**

Indicative content:

- Trend across a period: proton number increases, electrons are added to the same shell, atoms change from metallic to non-metallic; electron arrangement explains changes in reactivity and bonding.
- Trend down a group: atoms have more electron shells, outer electrons are further from nucleus so they are lost more easily in metals (reactivity increases down Group 1) or gained less easily in non-metals (reactivity decreases down Group 7).
- Periodic table order by atomic number gives evidence for protons and a structured arrangement of electrons in shells.
- Examples: Group 1 metals losing one electron to form +1 ions; noble gases having full outer shells and being unreactive.

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Question 9

states electron arrangement: 2,8,5 cao	**B1**
identifies that phosphorus has 5 electrons in its outer (third) shell	**M1**
explains phosphorus needs to share three more electrons to fill its outer shell (up to 8), so it forms three covalent bonds, eg with three chlorine atoms as in PCl_3	**A1**
links to periodic table position: phosphorus is in Group 5, and elements in this group have five outer electrons and typically form three covalent bonds to complete their outer shell	**B1**

Answer: Electron arrangement: 2,8,5. Phosphorus has five electrons in its outer shell so needs to share three more to complete it (reach 8); this is why it forms three covalent bonds, for example in PCl_3. As a Group 5 element, this pattern is typical of elements with five outer electrons.

Question 10

uses charges A2+ and B3- to find least common multiple approach	**M1**
shows balancing: 3 x A2+ gives total +6, 2 x B3- gives total -6	**M1**
states empirical formula A3B2 cao	**A1**
explains ionic compound is neutral because total positive and negative charges balance	**B1**

Answer: The lowest common multiple of the charge magnitudes 2 and 3 is 6. Three A2+ ions give 3 x (+2) = +6 and two B3- ions give 2 x (-3) = -6. The charges cancel, making the compound electrically neutral. The simplest whole-number ratio A:B is 3:2, so the empirical formula is A3B2.

Question 11

prediction: chlorine displaces iodine from potassium iodide	**B1**
reason: chlorine is more reactive than iodine and oxidises I^- to I_2	**M1**
states chloride ions are formed: $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$ or equivalent	**A1**
observational detail: brown/orange colour of iodine or blue-black with starch if added	**B1**

Answer: Iodine is displaced so the solution turns brown/orange as I_2 forms; chlorine oxidises I^- to I_2 and is reduced to Cl^-.

Question 12

recognises that the chloride ions in the resulting solution include those from the excess hydrochloric acid as well as those associated with the metal chloride	**B1**
calculates total chloride amount using $n(Cl^-) = 0.3545 / 35.45$	**M1**
total $n(Cl^-) = 0.0100$ mol	**A1**
uses the stated MCl2 stoichiometry and excess acid to obtain $2n(M) < 0.0100$, rather than assigning all chloride to MCl2	**M1**
$n(M) < 0.00500$ mol	**A1**
uses $Ar(M) = 0.327 / n(M)$, hence $Ar(M) > 65.4$	**M1**
none of the candidates is consistent with the stated conditions: all listed relative atomic masses are at most 65.4; zinc would use all 0.0100 mol HCl, leaving no excess acid	**A1**

Answer: None of the candidates is consistent with the stated data. Total $n(Cl^-) = 0.3545 / 35.45 = 0.0100$ mol includes chloride from excess hydrochloric acid. For MCl2, $2n(M) < 0.0100$, so $n(M) < 0.00500$ mol and $Ar(M) > 65.4$. All candidates have Ar at most 65.4; zinc would leave no excess acid. A unique relative atomic mass cannot be determined from these conditions.

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