

GCSE / IGCSE Chemistry – Atomic Structure and the Periodic Table

GCSE/IGCSE Chemistry (Edexcel/Cambridge/AQA style, Higher and Foundation content combined) · Total marks: 39 · Answers on the last page

Covers atoms and subatomic particles, isotopes and relative atomic mass, electron configuration, and periodic table structure and trends (Groups 1, 7 and 0). A calculator is allowed for Question 4; relative atomic masses should be taken to 1 decimal place. Allow about 40 minutes.

Section A – Atoms, particles and isotopes

1. Complete the following for a neutral atom of sodium, ${}_{11}^{23}\text{Na}$: state the number of protons, neutrons and electrons, and give the relative charge and relative mass of each type of subatomic particle. [4]
2. Define the term isotope, and state which two subatomic particle numbers stay the same between isotopes of an element and which one differs. [2]
3. Chlorine exists as two isotopes: ${}^{35}\text{Cl}$ (75% abundance) and ${}^{37}\text{Cl}$ (25% abundance).
 - (a) Calculate the relative atomic mass (A_r) of chlorine.
 - (b) Explain why the relative atomic mass of chlorine on the periodic table (35.5) is not a whole number. [4]
4. State what is meant by (a) atomic number and (b) mass number, and explain how both can be used to work out the number of neutrons in an atom. [3]

Section B – Electron configuration and the periodic table

5. Write the electron configuration (electron arrangement) of: (a) a magnesium atom ($Z = 12$) (b) a chlorine atom ($Z = 17$). [2]
6. Explain, in terms of electron configuration, why magnesium (electron configuration 2, 8, 2) forms an ion with charge 2+, and give the electron configuration of this ion. [3]
7. Explain how the position of an element in the periodic table (its group number and period number) relates to its electron configuration. [3]
8. State two pieces of evidence (from the modern periodic table) that support the idea that elements are arranged in order of increasing atomic (proton) number, and explain why Mendeleev left gaps in his early periodic table. [3]

Section C – Group trends (exam-style)

9. Lithium, sodium and potassium are all in Group 1 of the periodic table.
 - (a) Describe the trend in reactivity with water as you go down Group 1.
 - (b) Explain this trend in terms of atomic structure. [4]
10. Chlorine, bromine and iodine are Group 7 elements (halogens).
 - (a) Describe the trend in reactivity down Group 7.
 - (b) A displacement reaction occurs between chlorine gas and potassium bromide solution. Write a word equation and a balanced symbol equation for this reaction, and explain why it occurs. [5]

11. Explain why the noble gases (Group 0), such as helium, neon and argon, are described as unreactive/inert, and state the trend in boiling point down the group. [3]
12. An unknown Group 7 element X reacts with an aqueous solution of sodium iodide, and a colour change is observed showing that a displacement reaction has occurred, forming iodine. State, with a reason, whether X could be chlorine, and whether X could be astatine (the element below iodine in Group 7). [3]

Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

1. Sodium: protons = 11, neutrons = $23 - 11 = 12$, electrons = 11. Proton: relative charge +1, relative mass 1. Neutron: relative charge 0, relative mass 1. Electron: relative charge -1, relative mass approximately $\frac{1}{1836}$ (negligible/very small).
2. Isotopes are atoms of the same element (same number of protons) with different numbers of neutrons (and therefore different mass numbers). The number of protons (and electrons) stays the same; the number of neutrons differs.
3. (a) $A_r = (35 \times 0.75) + (37 \times 0.25) = 26.25 + 9.25 = 35.5$.
(b) The relative atomic mass is a weighted average of the masses of all the naturally occurring isotopes, based on their relative abundances; since chlorine's two isotopes occur in different proportions and have different mass numbers, the weighted average is not a whole number.
4. (a) Atomic number is the number of protons in the nucleus of an atom of an element.
(b) Mass number is the total number of protons and neutrons in the nucleus. Number of neutrons = mass number - atomic number.
5. (a) Magnesium: 2, 8, 2.
(b) Chlorine: 2, 8, 7.
6. Magnesium has 2 electrons in its outer shell. To achieve a stable, full outer shell (like a noble gas), it loses these 2 outer electrons, leaving 2 more protons than electrons and so an overall charge of 2+. The resulting Mg^{2+} ion has electron configuration 2, 8.
7. The period number equals the number of occupied electron shells in an atom of the element. The group number (for main groups) equals the number of electrons in the outer (highest energy) shell of an atom of the element, which also largely determines its chemical properties.
8. Evidence: elements in the same group have similar chemical properties/reactivity (e.g. Group 1 metals all react vigorously with water); properties change in a repeating (periodic) pattern across periods. Mendeleev left gaps for elements he predicted existed but had not yet been discovered, so that elements with similar properties would still line up in the same group; later discovered elements (e.g. germanium) fitted these gaps and confirmed his predictions.
9. (a) Reactivity with water increases going down Group 1 (lithium reacts steadily, sodium more vigorously, potassium violently, often igniting).
(b) Going down the group, atoms have more electron shells, so the single outer electron is further from the nucleus and more shielded by inner shells; it is therefore less strongly attracted to the nucleus and more easily lost, so the atom reacts (loses its outer electron) more readily/easily.
10. (a) Reactivity decreases going down Group 7.
(b) Word equation: chlorine + potassium bromide $\rightarrow$ potassium chloride + bromine. Symbol equation: $\text{Cl}_2 + 2\text{KBr} \rightarrow 2\text{KCl} + \text{Br}_2$. This occurs because chlorine is more reactive than bromine (a more reactive halogen displaces a less reactive halogen from its salt solution) — chlorine's smaller atomic radius means its outer shell is closer to the nucleus, so it attracts an extra electron more strongly than bromine does.
11. Noble gases have a full outer electron shell (a stable electron configuration), so they have little or no tendency to lose, gain or share electrons to form bonds, making them very unreactive/inert. Boiling point increases going down the group (as atomic size/number of electrons increases, so do the (weak) intermolecular forces between atoms).

12. X could be chlorine: chlorine is more reactive than iodine (higher up Group 7), so it can displace iodine from sodium iodide solution. X could not be astatine: astatine is below iodine in Group 7, so it is less reactive than iodine and could not displace it from solution.

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