AQA | Year 12 chemistry

Atomic structure

Questions & answers

46 original questions | 242 marks. Questions start on page 2. Work in the dotted spaces, then check the answers at the back. Use the values supplied in each question.

Atoms, ions & isotopes Q1-Q6

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Atoms, ions & isotopes

Question 1 | AQA | 4 marks

Positively charged particles are directed at a very thin metal foil. Most pass straight through. A very small proportion are deflected through large angles. Use these observations to explain two conclusions about atomic structure and why the results do not support a model in which positive charge is spread uniformly through the atom.

Question 2 | AQA | 6 marks

State the relative charge and relative mass of a proton, a neutron and an electron.

Question 3 | AQA | 4 marks

State where protons, neutrons and electrons are found in an atom. State where almost all of the mass of an atom is concentrated.

Question 4 | AQA | 3 marks

An ion contains 17 protons, 18 neutrons and 18 electrons. Give its element, mass number and charge.

Question 5 | AQA | 3 marks

For the ion $^{34}_{16}Q^{2-}$, state the number of protons, neutrons and electrons.

Question 6 | AQA | 3 marks

(a) Define the term isotope. [2]

(b) Explain why isotopes of the same element have the same chemical properties. [1]

How mass spectrometry works

Question 7 | AQA | 5 marks

The stages below are not in the correct order: acceleration, data analysis, detection, drift, ionisation.

(a) Put the stages in the correct order. [2]

(b) State how the ions are accelerated and the energy condition produced. [2]

(c) Explain why the drift region is evacuated. [1]

Question 8 | AQA | 2 marks

Describe what happens when a positive ion reaches the detector and explain how the detector signal is related to abundance.

Question 9 | AQA | 4 marks

(a) Write an equation, including state symbols, for the formation of a singly charged positive ion from a gaseous atom Y by electron impact. [1]

(b) Explain how the ion produces a detector signal and how it gives relative abundance. [3]

Question 10 | AQA | 6 marks

A large organic molecule M is analysed using electrospray ionisation.

(a) Describe how $[MH]^+$ ions are produced. [4]

(b) Write the equation for forming $[MH]^+$. [1]

(c) A singly charged $[MH]^+$ peak is at m/z 587.4. Determine M_r of M. [1]

Question 11 | AQA | 3 marks

Two singly charged ions are given the same kinetic energy. They travel the same flight distance. One ion is heavier. Explain why the heavier ion reaches the detector later.

TOF calculations

Question 12 | AQA | 5 marks

A singly charged ion has relative isotopic mass 72.0 and kinetic energy 8.25×10^{-16} J. It travels through a 1.40 m flight tube. Calculate its time of flight in μs to three significant figures.

Use $L = 6.022 \times 10^{23}$ mol^{-1}. KE = ½mv^2; v = d/t.

Question 13 | AQA | 5 marks

An ion travels 1.12 m in 11.4 μs. Its kinetic energy is 6.75×10^{-16} J. Calculate its mass number.

Use $L = 6.022 \times 10^{23}$ mol^{-1}. KE = ½mv^2; v = d/t.

Question 14 | AQA | 5 marks

A singly charged ion has relative isotopic mass 96.0, kinetic energy 7.40×10^{-16} J and time of flight 18.5 μs. Calculate the flight-tube length to three significant figures.

Use $L = 6.022 \times 10^{23}$ mol^{-1}. KE = ½mv²; v = d/t.

Question 15 | AQA | 7 marks

A^+ and B^+ have the same kinetic energy and travel the same distance. Relative isotopic mass of A = 64.0; t_a = 13.6 μs; t_β = 15.3 μs.

(a) Why can you not calculate the mass of B directly from its KE equation alone? [1]

(b) Set the kinetic energies equal and calculate the relative isotopic mass of B. Show why distance cancels. [5]

(c) Why can the masses and speeds not be cancelled? [1]

Mass spectra & relative masses

Question 16 | AQA | 6 marks

m/z	Relative abundance / %
19.9924	90.48
20.9938	0.27
21.9914	9.25

(a) State the quantity shown on each axis of an elemental mass spectrum. [2]

(b) Calculate the relative atomic mass to four significant figures. [3]

(c) Identify the element. [1]

Question 17 | AQA | 10 marks

A singly charged ion has KE = 7.50×10^{-16} J and travels 1.25 m in 10.92 μs. Use L = 6.022×10^{23} mol^{-1}.

(a) Calculate its mass number. [5]

(b) The element has exactly two isotopes. The other mass number is two greater. Currents are 3.20 nA for the lighter isotope and 1.10 nA for the heavier. Calculate their percentage abundances. [2]

(c) Calculate A_r to three decimal places. [2]

(d) Explain why the heavier isotope gives the smaller current. [1]

Question 18 | AQA | 6 marks

Stretch: this molecular-isotope probability calculation goes beyond the usual mononuclear-ion A_r calculation requirement.

Element X has isotopes ^{24}X and ^{26}X with abundances 79.0% and 21.0%. X_2 is analysed by electron impact. Assume molecular ions form without fragmentation.

(a) State the three m/z values for X_2^+. [2]

(b) Calculate the expected percentage ratio of the peaks. [3]

(c) Explain why the middle peak can form in two ways. [1]

Question 19 | AQA | 4 marks

An element has isotopes with accurate relative isotopic masses 78.918 and 80.916. The lighter : heavier abundance ratio is 4.35 : 1.00. Calculate A_r to three decimal places.

Question 20 | AQA | 4 marks

An element has A_r = 58.573. One isotope has accurate relative isotopic mass 57.935 and abundance 68.0%. The second isotope has abundance 32.0%.

(a) Calculate the accurate relative isotopic mass of the second isotope to three decimal places. [3]

(b) State its mass number. [1]

Question 21 | AQA | 4 marks

Two isotopes have relative isotopic masses 10 and 11. A_r = 10.8. Calculate their percentage abundances.

Question 22 | AQA | 3 marks

An electron-impact spectrum has peaks at m/z 41, 55 and 70. The base peak is at 41; the molecular-ion peak is at 70.

(a) State the relative molecular mass. [1]

(b) Explain the term base peak and why it does not necessarily give M_r. [2]

Question 23 | AQA | 8 marks

A reference ion of relative isotopic mass 125.0 takes 18.6 μs. A singly charged $[MH]^+$ ion takes 23.3 μs in the same instrument. Both have the same kinetic energy and travel the same distance.

(a) Calculate the relative mass of $[MH]^+$ on the carbon-12 scale. [4]

(b) Determine M_r of M. [1]

(c) Why is electrospray often used for a large molecule? [1]

(d) An electron-impact spectrum of M has a base peak at 43 and molecular-ion peak at 195. Which confirms M_r, and why? [2]

Question 24 | AQA | 5 marks

(a) Define relative atomic mass. [2]

(b) Define relative molecular mass. [2]

(c) State the term used instead of relative molecular mass for an ionic substance. [1]

Shells, sub-shells & orbitals

Question 25 | AQA | 5 marks

(a) State the maximum number of electrons in s, p and d sub-shells. [3]

(b) Explain why a p sub-shell holds up to six electrons. [2]

Electron configurations

Question 26 | AQA | 3 marks

(a) Put 3p, 4s, 3d and 4p in filling order. [1]

(b) State the maximum number of electrons in 3d. [1]

(c) State the principal energy level number of an electron in 4p. [1]

Question 27 | AQA | 4 marks

Atomic numbers: P = 15, Ca = 20, Se = 34.

(a) Write the full electron configuration of phosphorus. [1]

(b) Write the full electron configuration of calcium. [1]

(c) Write the full electron configuration of selenium. [1]

(d) Write selenium using [Ar] shorthand. [1]

Question 28 | AQA | 4 marks

Atomic numbers: Cr = 24, Cu = 29.

(a) Write chromium using [Ar] shorthand. [1]

(b) Write copper using [Ar] shorthand. [1]

(c) Describe the 3d occupancy in each. [2]

Question 29 | AQA | 5 marks

Atomic numbers: O = 8, Ca = 20, Fe = 26.

(a) Write the electron configuration of O^{2-}. [1]

(b) Write the electron configuration of Ca^{2+}. [1]

(c) Write the electron configuration of Fe^{2+}. [1]

(d) Write the electron configuration of Fe^{3+}. [1]

(e) Which sub-shell loses electrons first when iron forms a positive ion? [1]

Question 30 | AQA | 4 marks

X^{3+} has configuration [Ar] $3d^2$. Relevant atomic numbers: Sc = 21, Ti = 22, V = 23, Cr = 24.

(a) How many electrons are in X^{3+}? [1]

(b) Identify X. [1]

(c) Write the neutral atom's configuration. [1]

(d) Explain how you reconstructed it. [1]

Question 31 | AQA | 8 marks

Y^{2+} has configuration [Ar] $3d^5$. Y has $Z \leq 36$. Relevant atomic numbers: Cr = 24, Mn = 25, Fe = 26, Co = 27.

(a) How many electrons are in Y^{2+}? [1]

(b) Determine the proton number and identity of Y. [2]

(c) Write the neutral Y configuration. [1]

(d) Write the Y^{3+} configuration. [1]

(e) Which sub-shell loses electrons first? [1]

(f) A student says Y is iron because Fe^{3+} is also [Ar] $3d^5$. Explain the error. [2]

Question 32 | AQA | 9 marks

Element E has proton number 34 and forms E^{2-}.

Element	Ge	As	Se	Br	Kr
Atomic number	32	33	34	35	36

(a) Identify E. [1]

(b) Write the full configuration of E. [1]

(c) Write the full configuration of E^{2-}. [1]

(d) State the number of electrons in E^{2-}. [1]

(e) Final electrons enter 3s, 3p, 3d and 4f in four different atoms. State their blocks. [4]

(f) Explain how a block is named. [1]

Ionisation energies

Question 33 | AQA | 5 marks

(a) Define first ionisation energy. [3]

(b) Write the first-ionisation equation for magnesium, with state symbols. [1]

(c) State the units. [1]

Question 34 | AQA | 3 marks

(a) Write the equation for the second ionisation energy of magnesium. [1]

(b) Write the equation for the third ionisation energy of aluminium. [1]

(c) Is ionisation endothermic or exothermic? [1]

Question 35 | AQA | 5 marks

(a) State the three main factors controlling attraction between the nucleus and the electron being removed. [3]

(b) Why is an electron in a higher-energy sub-shell easier to remove? [2]

Question 36 | AQA | 4 marks

Na has IE_1 = 496 and IE_2 = 4562 kJ mol^{-1}. Mg has IE_1 = 738 and IE_2 = 1451 kJ mol^{-1}. Explain why the second IE of sodium is much greater than that of magnesium. Atomic numbers: Na = 11, Mg = 12.

Question 37 | AQA | 6 marks

Element	First IE / kJ mol⁻¹
Na	496
Mg	738
Al	578
Si	787
P	1012
S	1000
Cl	1251
Ar	1521

(a) Describe the general trend across Period 3. [1]

(b) Explain the trend. [3]

(c) Identify the two decreases. [1]

(d) What do the decreases show about electron arrangement? [1]

Question 38 | AQA | 4 marks

Mg is [Ne] $3s^2$; Al is [Ne] $3s^2$ $3p^1$.

(a) Which sub-shell loses the first electron in Al? [1]

(b) Explain why Al has a lower first IE than Mg. [3]

Question 39 | AQA | 4 marks

(a) State the final sub-shell occupancy of phosphorus and sulfur. Atomic numbers: P = 15, S = 16. [2]

(b) Explain why sulfur has a slightly lower first ionisation energy than phosphorus. [2]

Question 40 | AQA | 9 marks

Species	Configuration	First IE / kJ mol^{-1}
A	[Ne] 3s^2	738
B	[Ne] 3s^2 3p^1	578
C	[Ne] 3s^2 3p^3	1012
D	[Ne] 3s^2 3p^4	1000

All four are in Period 3: Na, Mg, Al, Si, P, S, Cl, Ar.

(a) Identify A, B, C and D. [4]

(b) Explain why the first ionisation energy of B is lower than that of A. [3]

(c) Explain why the first ionisation energy of D is lower than that of C. [2]

Question 41 | AQA | 5 marks

Element	First IE / kJ mol^{-1}
Be	900
Mg	738
Ca	590
Sr	550
Ba	503

(a) Describe the trend in first ionisation energy down Group 2. [1]

(b) Explain this trend in first ionisation energy. [4]

Question 42 | AQA | 5 marks

A Period 3 element has successive IEs of 786, 1577, 3232, 4356 and 16 091 kJ mol^{-1}. Period 3: Na, Mg, Al, Si, P, S, Cl, Ar.

(a) Where is the large jump? [1]

(b) How many outer-shell electrons? [1]

(c) Identify the element. [1]

(d) Write its full electron configuration. [1]

(e) Explain the jump. [1]

Question 43 | AQA | 7 marks

A Period 3 element has successive IEs of 1000, 2250, 3360, 4560, 7000, 8500, 27 100 and 31 800 kJ mol^{-1}. Period 3: Na, Mg, Al, Si, P, S, Cl, Ar.

(a) Identify the largest jump. [1]

(b) State the number of outer-shell electrons. [1]

(c) Identify the element. [1]

(d) Write its full configuration. [1]

(e) Explain the sharp rise. [3]

Question 44 | AQA | 6 marks

Al has successive IEs of 578, 1817, 2745 and 11 578 kJ mol^{-1}.

(a) Write the fourth-ionisation equation, including state symbols. [1]

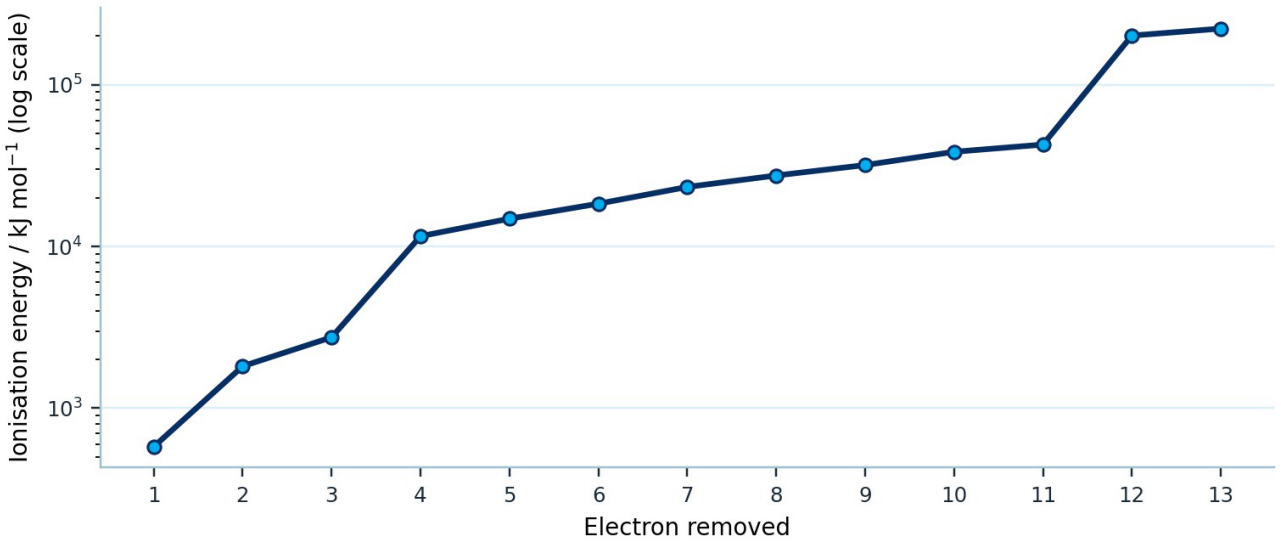
(b) Explain why IE_4 is much greater than IE_3. [3]

(c) Calculate IE_4 / IE_3 to three significant figures. [1]

(d) What does this show about the number of outer-shell electrons? [1]

Question 45 | AQA | 10 marks

The graph shows all thirteen successive IEs of an unknown Period 3 element. Period 3: Na, Mg, Al, Si, P, S, Cl, Ar.



(a) Identify both large jumps. [2]

(b) State the number of electrons in the outer shell and second shell. [2]

(c) Deduce the shell arrangement and identify the element. [2]

(d) Write its full configuration. [1]

(e) Explain the first large jump. [2]

(f) Why do successive IEs increase even before a new shell is reached? [1]

Question 46 | AQA | 12 marks

M has isotopes at m/z 24, 25 and 26 with abundances 78.99%, 10.00% and 11.01%. Relevant atomic numbers: Na = 11, Mg = 12, Al = 13, Ca = 20.

(a) Calculate A_r to two decimal places. [2]

(b) Identify M. [1]

(c) Write the full configuration of M. [1]

(d) Write the configuration of M^{2+}. [1]

(e) Write the third-ionisation equation. [1]

(f) The first three IEs are 738, 1451 and 7733 kJ mol^{-1}. Explain what these show about the outer electrons and the next electron removed. [4]

(g) Calcium has first IE 590 kJ mol^{-1}. Why is this lower than M's? [2]

Answers & marking points

Equivalent correct chemistry and working are acceptable. Use the question number to find the matching answer.

Atoms, ions & isotopes

Question 1 | AQA | 4 marks

- Most particles pass through, so most of the atom is empty space. [1]
- Large deflections require positive charge concentrated in a very small central nucleus. [1]
- Most mass is also concentrated in the nucleus. [1]
- Diffuse positive charge would cause only small deflections, so cannot explain the rare large deflections. [1]

Question 2 | AQA | 6 marks

- Proton: +1; relative mass 1. [2]
- Neutron: 0; relative mass 1. [2]
- Electron: −1; relative mass approximately 1/1840. [2]

The electron has a very small mass, not zero mass.

Question 3 | AQA | 4 marks

- Protons: nucleus. [1]
- Neutrons: nucleus. [1]
- Electrons: regions around the nucleus. [1]
- Almost all mass is in the nucleus. [1]

Question 4 | AQA | 3 marks

- Chlorine, because Z = 17. [1]
- A = number of protons + number of neutrons
A = 17 + 18 = 35. [1]
- One extra electron gives a 1− charge: $^{35}Cl^-$. [1]

Question 5 | AQA | 3 marks

- Protons = 16. [1]
- Neutrons = 34 − 16 = 18. [1]
- Electrons = 16 + 2 = 18. [1]

Question 6 | AQA | 3 marks

(a) Atoms with the same number of protons but different numbers of neutrons. [2]

(b) They have the same electron configuration. [1]

How mass spectrometry works

Question 7 | AQA | 5 marks

(a) Ionisation → acceleration → drift → detection → data analysis. [2]

(b) An electric field accelerates the ions [1], giving ions of the same charge the same kinetic energy. [1]

(c) To prevent ions colliding with gas particles. [1]

Question 8 | AQA | 2 marks

• The positive ion gains an electron, producing a current. [1]

• The size of the current is proportional to the abundance of that ion. [1]

Question 9 | AQA | 4 marks

(a) $Y(g) + e^- \rightarrow Y^+(g) + 2e^-$. The net ionisation equation $Y(g) \rightarrow Y^+(g) + e^-$ also shows the loss of one electron. [1]

(b) The ion gains an electron at the detector [1]. Electron movement produces a current [1]. A larger current indicates greater abundance [1].

Question 10 | AQA | 6 marks

(a) Dissolve M in a volatile solvent [1]; inject through a fine needle at high pressure [1]; apply high voltage to form charged droplets [1]; M gains a proton as the solvent evaporates, forming $[MH]^+$ [1].

(b) $M + H^+ \rightarrow [MH]^+$. [1]

(c) $M_r = 587.4 - 1 =$ **586.4**. [1]

Question 11 | AQA | 3 marks

• Both ions have the same kinetic energy. [1]

• From $KE = \frac{1}{2}mv^2$, the heavier ion must have a lower speed. [1]

• It takes longer to travel the same distance. [1]

TOF calculations

Question 12 | AQA | 5 marks

1. Target t: $t = d/v$. Find v using $v = \sqrt{(2KE/m)}$.

2. $m = (72.0 \times 10^{-3}) / (6.022 \times 10^{23}) = 1.1956 \times 10^{-25}$ kg. [1]

3. Rearrange KE: $v = \sqrt{(2KE/m)}$. [1]

4. $v = \sqrt{(2KE/m)}$
$v = \sqrt{[(2 \times 8.25 \times 10^{-16})/(1.1956... \times 10^{-25})]} = 1.1748 \times 10^5$ m s^{-1}. [1]

5. $t = d/v$.
$t = 1.40/(1.1747517... \times 10^5) = 1.1917 \times 10^{-5}$ s. [1]

6. t = **11.9 µs**. [1]

Question 13 | AQA | 5 marks

1. Target mass: $m = 2KE/v^2$. First find the unknown speed.

2. $v = d/t$.
$v = 1.12/(11.4 \times 10^{-6}) = 9.8246 \times 10^4$ m s^{-1}. [1]

3. $m = 2KE/v^2$. [1]

4. $m = 2KE/v^2$
$m = (2 \times 6.75 \times 10^{-16})/(9.8245614... \times 10^4)^2 = 1.3986 \times 10^{-25}$ kg. [1]

5. Molar mass = m × L × 1000.
Molar mass = $(1.3986... \times 10^{-25}) \times (6.022 \times 10^{23}) \times 1000 = 84.23$ g mol^{-1}. [1]

6. Mass number = **84**, a whole number. [1]

Question 14 | AQA | 5 marks

1. Target d: $d = vt$. Find v using $v = \sqrt{(2KE/m)}$.

2. $m = (96.0 \times 10^{-3}) / (6.022 \times 10^{23}) = 1.5942 \times 10^{-25}$ kg. [1]

3. $v = \sqrt{(2KE/m)}$. [1]

4. $v = \sqrt{(2KE/m)}$
$v = \sqrt{[(2 \times 7.40 \times 10^{-16})/(1.5941547... \times 10^{-25})]} = 9.6353 \times 10^4$ m s^{-1}. [1]

5. $d = vt = (9.6353 \times 10^4)(18.5 \times 10^{-6})$. [1]

6. d = **1.78 m**. [1]

Question 15 | AQA | 7 marks

(a) Mass and speed are both unknown. [1]

(b)

1. $\frac{1}{2}m_a v_a^2 = \frac{1}{2}m_\beta v_\beta^2$. [1]

2. Multiply by 2: $m_a v_a^2 = m_\beta v_\beta^2$. [1]

3. Substitute $v = d/t$: $m_a(d/t_a)^2 = m_\beta(d/t_\beta)^2$. [1]

4. The identical d^2 factors cancel: $m_a/t_a^2 = m_\beta/t_\beta^2$. [1]

5. $m_\beta = m_a(t_\beta/t_a)^2$.
$m_\beta = 64.0(15.3/13.6)^2 =$ **81.0**. [1]

(c) They have different masses and speeds, so these are not identical factors. [1]

Mass spectra & relative masses

Question 16 | AQA | 6 marks

(a) x-axis: m/z. y-axis: relative abundance or intensity. [2]

(b) $A_r = [(19.9924 \times 90.48) + (20.9938 \times 0.27) + (21.9914 \times 9.25)] / 100 = 20.18001128 =$ **20.18**. Correct weighted sum [1], denominator [1], answer [1].

(c) Neon. [1]

Question 17 | AQA | 10 marks

(a) v = d/t.
v = 1.25/(10.92 × 10^{-6}) = 1.1447 × 10^{5} m s^{-1} [1].
m = 2KE/v^2 [1].
m = (2 × 7.50 × 10^{-16})/(1.1446886... × 10^{5})^2 = 1.14476544 × 10^{-25} kg [1].
Relative mass = m × L × 1000.
Relative mass = (1.14476544 × 10^{-25}) × (6.022 × 10^{23}) × 1000 = 68.94 [1].
Mass number = **69** [1].

(b) Total current = 4.30 nA. Isotope 69: 3.20/4.30 × 100 = **74.4%** [1]. Isotope 71: **25.6%** [1].

(c) A_r = Σ(isotopic mass × abundance)/Σ(abundance)
A_r = [69(3.20) + 71(1.10)]/4.30 [1] = **69.512** [1].

(d) It is less abundant, so fewer ions of that isotope arrive. [1]

Question 18 | AQA | 6 marks

(a) m/z = **48, 50, 52**. [2]

(b) P(48) = 0.790^2 = 62.41% [1]; P(50) = 2(0.790)(0.210) = 33.18% [1]; P(52) = 0.210^2 = 4.41% [1]. Ratio = 62.41 : 33.18 : 4.41.

(c) Mixed pairs can be ^{24}X–^{26}X or ^{26}X–^{24}X, so double the mixed-isotope probability. [1]

Question 19 | AQA | 4 marks

1. Use the ratio as weighting factors. [1]

2. A_r = [(78.918 × 4.35) + (80.916 × 1.00)] / 5.35. [1]

3. A_r = 79.2914579... [1]

4. A_r = **79.291**. [1]

Question 20 | AQA | 4 marks

(a) 58.573 = 57.935(0.680) + 0.320x [1]. x = [58.573 − 57.935(0.680)] / 0.320 [1] = 59.92875 = **59.929** [1].

(b) Mass number = **60**. [1]

Question 21 | AQA | 4 marks

1. Let mass 10 have abundance x%; mass 11 has (100 − x)%.

2. 10.8 = [10x + 11(100 − x)]/100.

3. 1080 = 1100 − x, so x = 20.

4. Mass 10: **20%**; mass 11: **80%**.

Question 22 | AQA | 3 marks

(a) M_r = **70**. [1]

(b) The base peak is the most intense peak, assigned relative intensity 100 [1]. It may be a fragment ion, so it need not give M_r [1].

Question 23 | AQA | 8 marks

(a) Equal KE and distance give m/t^2 = constant [1]. $m_2/m_1 = (t_2/t_1)^2$ [1]. $m_2 = m_1(t_2/t_1)^2$
$m_2 = 125.0(23.3/18.6)^2$ [1] = 196.153... ≈ **196** to 3 s.f. [1].

(b) $M_r \approx 196.153... - 1 = 195.153... \approx$ **195**. [1]

(c) Less fragmentation, so the large molecule is more likely to remain intact. [1]

(d) Use m/z 195 because it is the intact molecular ion [1]. The intense fragment at 43 does not give M_r [1].

Question 24 | AQA | 5 marks

(a) The weighted mean mass of an atom of an element compared with one-twelfth of the mass of a carbon-12 atom. [2]

(b) The mean mass of a molecule compared with one-twelfth of the mass of a carbon-12 atom. [2]

(c) Relative formula mass. [1]

Shells, sub-shells & orbitals

Question 25 | AQA | 5 marks

(a) s: 2; p: 6; d: 10. [3]

(b) Three orbitals [1], each holding a maximum of two electrons [1].

Electron configurations

Question 26 | AQA | 3 marks

(a) 3p → 4s → 3d → 4p. [1]

(b) 10. [1]

(c) n = 4. [1]

Question 27 | AQA | 4 marks

(a) P: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$. [1]

(b) Ca: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$. [1]

(c) Se: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^4$. [1]

(d) Se: [Ar] $3d^{10}\ 4s^2\ 4p^4$. [1]

Question 28 | AQA | 4 marks

(a) Cr: [Ar] $3d^5\ 4s^1$. [1]

(b) Cu: [Ar] $3d^{10}\ 4s^1$. [1]

(c) Chromium: half-filled 3d [1]. Copper: full 3d [1].

Question 29 | AQA | 5 marks

(a) O^{2-}: $1s^2\ 2s^2\ 2p^6$. [1]

(b) Ca^{2+}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$, or [Ar]. [1]

(c) Fe^{2+}: [Ar] $3d^6$. [1]

(d) Fe^{3+}: [Ar] $3d^5$. [1]

(e) 4s is emptied before 3d. [1]

Question 30 | AQA | 4 marks

(a) 18 + 2 = 20 electrons. [1]

(b) Vanadium: 20 + 3 = 23 electrons in the neutral atom. [1]

(c) V: [Ar] $3d^3\ 4s^2$. [1]

(d) Reverse the 3+ charge by returning one electron to 3d and two to 4s. [1]

Question 31 | AQA | 8 marks

(a) 23. [1]

(b) Z = 23 + 2 = 25 [1], manganese [1].

(c) Mn: [Ar] $3d^5\ 4s^2$. [1]

(d) Mn^{3+}: [Ar] $3d^4$. [1]

(e) 4s before 3d. [1]

(f) Charge must be used as well as electron count [1]. Fe^{3+} is [Ar] $3d^5$, but Fe^{2+} is [Ar] $3d^6$, so Y^{2+} cannot be Fe^{2+} [1].

Question 32 | AQA | 9 marks

(a) Selenium, Se. [1]

(b) Se: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^4$. [1]

(c) Se^{2-}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$. [1]

(d) 36 electrons. [1]

(e) s, p, d and f blocks respectively. [4]

(f) The type of sub-shell receiving the differentiating electron gives the block name. [1]

Ionisation energies

Question 33 | AQA | 5 marks

(a) Energy required to remove one electron from each atom [1] in one mole of gaseous atoms [1] to form one mole of gaseous 1+ ions [1].

(b) $Mg(g) \rightarrow Mg^+(g) + e^-$. [1]

(c) kJ mol^{-1}. [1]

Question 34 | AQA | 3 marks

(a) $Mg^{+}(g) \rightarrow Mg^{2+}(g) + e^{-}$. [1]

(b) $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^{-}$. [1]

(c) Endothermic. [1]

Question 35 | AQA | 5 marks

(a) Nuclear charge [1], distance from the nucleus [1], shielding by inner electrons [1].

(b) It is already at higher energy / less strongly attracted [1], so less additional energy is required to remove it [1].

Question 36 | AQA | 4 marks

- Na^{+} is $1s^2\ 2s^2\ 2p^6$: the second electron is removed from n = 2. [1]
- Mg^{+} is $1s^2\ 2s^2\ 2p^6\ 3s^1$: its second electron is removed from 3s. [1]
- The electron in Na^{+} is closer to the nucleus and less shielded. [1]
- It is more strongly attracted and requires much more energy to remove. [1]

Question 37 | AQA | 6 marks

(a) First IE generally increases from Na to Ar. [1]

(b) Nuclear charge increases [1]. Electrons enter the same principal shell, so inner-shell shielding is broadly similar [1]. Stronger attraction means more energy is required [1].

(c) Mg → Al and P → S. Both needed. [1]

(d) Evidence for different sub-shell energies and electron pairing within orbitals. [1]

Question 38 | AQA | 4 marks

(a) 3p. [1]

(b) The 3p electron is higher in energy than 3s [1] and slightly more shielded [1], so it is less strongly attracted / easier to remove [1].

Question 39 | AQA | 4 marks

(a) P: $3p^3$ [1]. S: $3p^4$ [1].

(b) Sulfur has an electron pair in one 3p orbital [1]. Repulsion within that pair makes an electron easier to remove [1].

Question 40 | AQA | 9 marks

(a) A = Mg; B = Al; C = P; D = S. [4]

(b) B loses 3p rather than 3s [1]. The 3p electron is higher in energy / slightly more shielded [1], so it is easier to remove [1].

(c) D has a pair in a 3p orbital [1]. Pair repulsion makes one electron easier to remove [1].

Question 41 | AQA | 5 marks

(a) First IE decreases. [1]

(b) The outer electron occupies a higher principal shell [1], is further from the nucleus [1] and has more shielding [1]. These outweigh increased nuclear charge, so attraction is weaker and less energy is required [1].

Question 42 | AQA | 5 marks

(a) Between IE_4 and IE_5. [1]

(b) Four. [1]

(c) Silicon, Si. [1]

(d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$. [1]

(e) The fifth electron comes from an inner shell and is more strongly attracted to the nucleus. [1]

Question 43 | AQA | 7 marks

(a) Between IE_6 and IE_7. [1]

(b) Six. [1]

(c) Sulfur, S. [1]

(d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$. [1]

(e) The seventh electron comes from n = 2 [1]. It is closer and less shielded [1], so is much more strongly attracted and requires far more energy [1].

Question 44 | AQA | 6 marks

(a) $Al^{3+}(g) \rightarrow Al^{4+}(g) + e^-$. [1]

(b) Three outer electrons have already been removed [1]. The fourth comes from an inner shell, closer / less shielded [1], so is much more strongly attracted [1].

(c) 11 578 / 2745 = **4.22**. [1]

(d) Al has three outer-shell electrons. [1]

Question 45 | AQA | 10 marks

(a) After IE_3 and IE_{11}. [2]

(b) Outer shell: 3. Second shell: 8. [2]

(c) 2,8,3; aluminium. [2]

(d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$. [1]

(e) The next electron comes from n = 2 [1], closer / less shielded and more strongly attracted [1].

(f) Each electron is removed from an increasingly positive ion, so remaining electrons are more strongly attracted. [1]

Question 46 | AQA | 12 marks

(a) A_r = Σ(isotopic mass × abundance)/Σ(abundance)
A_r = [24(78.99) + 25(10.00) + 26(11.01)]/100 [1] = **24.32** [1].

(b) Magnesium, Mg. [1]

(c) $1s^2\ 2s^2\ 2p^6\ 3s^2$. [1]

(d) $1s^2\ 2s^2\ 2p^6$ or [Ne]. [1]

(e) $Mg^{2+}(g) \rightarrow Mg^{3+}(g) + e^-$. [1]

(f) Large jump between IE_2 and IE_3 [1], hence two outer electrons [1]. The third comes from an inner shell [1], closer / less shielded and much more strongly attracted [1].

(g) Ca has another occupied shell, so the outer electron is further away and more shielded [1]. Attraction is weaker, requiring less energy [1].