Chapter 1 Solutions

Note:
1. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the mark scheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by OWTTE (or words to that effect).
2. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then follow through marks should be awarded. When marking, indicate this by adding ECF (error carried forward) on the script.
3. Do not penalize candidates for errors in units or significant figures, unless it is specifically referred to in the answer key.
4. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the answer key. Similarly, if the formula is specifically asked for, unless directed otherwise in the answer key, do not award a mark for a correct name.
5. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the answer key.
6. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the answer key.

Key

- A – Answer marking point
- M – Method marking point
- B – Award once written
- G – Graph marking point
- MA – Both method **and** answer must be present

1 Magnesium is essential in our bodies. For example, magnesium needed to regulate our muscle movements.

(a) Magnesium exists as the Mg^{2+} ion most of the times in our body.

(i) Write down the number of electrons, protons and full electronic configuration of the Mg^{2+} ion. [1]

10 electrons
12 protons
$1s^2\ 2s^2\ 2p^6$

All or nothing - B1

(ii) State how the mass of a Mg^{2+} ion is distributed. [1]

B1 – Mass is concentrated in the nucleus containing all protons and neutrons
Electrons surrounding nucleus hold negligible mass

(iii) The Mg^{2+} ion exists as predominantly 2 isotopes. In a human body, it is found that 73.4% of the Mg^{2+} ions exist as $^{24}Mg^{2+}$, while the rest exists as $^{25}Mg^{2+}$. Calculate the relative mass of Mg^{2+} ions in the body, to 2 decimal places. [1]

MA1 – Relative mass = 24(0.734) + 25(1-0.734) = 24.27

(b) Magnesium is located in Period 3 of the Periodic Table.

The *first ionisation energies* of each element in Period 3 follow a certain trend.

(i) Explain what is meant by *first ionisation energy*. Include an equation in your answer. [2]

A1 – Correct definition
1^{st} IE of X is the energy required to remove 1 mole of electrons from 1 mole of atoms of X forming 1 mole of unipositively charged X^+ ions.

B1 – Correct equation with state symbols
$X (g) \rightarrow X^+ (g) + e^-$

(ii) Draw a graph of the first ionisation energy against consecutive elements in Period 3 only. Numerical values are **not** needed.

Include an explanation, **below** your graph, for:

- The general trend of the first ionisation energy of elements across Period 3
- Any anomalies

[6]

Your graph should also illustrate these trends.

G1 – Correctly labelled axes + general trend (increasing)
A1 – Increasing nuclear charge, but electrons added to same outer shell, shielding effect is relative constant.

G1 – Anomaly 1 & 2: Slight drop from Mg → Al AND slight drop from P → S
A1 – Explains anomaly 1: 3p electron further away from nucleus and experiences better shielding compared to 3s electron
A1 – Explains anomaly 2: Paired 3p electron in S experiences interelectronic repulsion, but unpaired 3p electron does not experience that

B1 – Links IE to strength of electrostatic attraction electron to nucleus (OWTTE)

(iii) Another element in Period 3 has the following ionisation energies.

I.E. represents ionisation energy.

I.E.	1st	2nd	3rd	4th	5th	6th	7th	8th
log (I.E.)	6.28	7.03	7.39	7.67	8.06	8.23	9.29	9.43

[2]

Deduce this element.

A1 – Sulfur (Mark awarded only if there's attempt to explain)
A1 – All 3 pts (award 0.5 for 2 pts)

- Largest jump from 6^{th} to 7^{th} I.E.
- 7^{th} electron from an inner quantum shell
- 6 valence electrons / element is in Group 16

A logarithm scale is used, so that's why the numbers are smaller!

2 Mercury lamps used to light our streets. Some mercury was vapourised in a lamp. A filament then discharged electrons of enough energy to knock out electrons in lower energy level orbitals in mercury. Electrons from higher energy orbitals will then lose energy, filling up the vacant lower energy orbitals. In this process, a photon carrying an energy that is exactly the difference between the higher and lower energy level orbitals is emitted. A photon is what makes us able to see light of different colours.

(a) In this process, mercury may be ionised too. Mercury is in Group 12.

(i) State whether zinc has a lower or higher first ionisation energy than cadmium, both of which are Group 12 metals, explaining your answer. [2]

A1 – Higher (Mark awarded only if there's attempt to explain)
A1 – Any 3 pts (award 0.5 for 2 pts)

- Zinc is above cadmium
- Zinc has less principal quantum shells
- Valence electrons in zinc nearer to nucleus
- Valence electrons experience stronger electrostatic attraction to nucleus

Comparison can be done with cadmium (e.g. cadmium is below zinc)

(ii) Compare the first ionisation energies of platinum, gold and mercury, explaining your answer. [2]

A2 – All pts (award 1 for 3 pts + correct conclusion)

- Identifies they are transition metals in same Period
- Increasing nuclear charge from Pt to Hg
- But electrons added to inner d subshell (reject orbital)
- Thereby nullifying effect of an additional proton on attracting a valance electron (to a considerable extent)

- Because shielding effect remains relatively invariant
- So first ionisation energies are **relatively invariant / around the same** (reject answer implying that they are the same / constant etc.)

(b) Mercury is in Period 6 of the Periodic Table.

Sketch, on **separate** axes, **all** the orbitals in the 5d subshell. [2]

G2 – all 5 correct (award 1 for any 3 correct)

1 correct sketch must contain
- Labels of axes (x, y, z)
- Correct shape (including symmetry)
- Label of orbital name

(c) A mercury lamp typically emits green light. When analysed further, 3 main wavelengths of visible light, 404.7 nm, 435.8 nm, 546.1 nm were found.

The relationship between the energy of a photon, *E*, expressed in eV (electron volts), and the wavelength, *λ*, expressed in nm, is given below.

$$E = \frac{1240}{\lambda}$$

No other wavelengths of light (within the visible spectrum), was found to be emitted.

(i) Suggest why the observation of only discrete wavelengths of light being emitted proves that the energy levels of an orbital and subshell are discrete. [1]

A1 – Discrete wavelengths → Discrete difference in energy levels (as implied by formula) → So energy levels of orbitals and subshells are discrete, instead of a range / continuous (OWTTE)

Accept explanation through contradiction
A1 – Non-discrete energy levels → Continuous energy levels → So energy of emitted can be a range too → Thus there's a range of wavelengths emitted → But that's non-discrete (OWTTE)

(ii) A mercury lamp has a power of 40 J s^{-1}. Assuming that only photons of 404.7 nm, 435.8 nm, 546.1 nm were emitted, and rate of emission of photons of all wavelengths are the same, calculate the number of photons emitted by the lamp in 1 second. [3]

[1 eV = 1.60×10^{-19} J]

M1 – Attempt to find total energy when 1 photon each with wavelength 404.7 nm, 435.8 nm, 546.1 nm emitted

E_{total} = 8.180 eV

M1 – Attempt to find the number of photons of 1 particular wavelength emitted in 1 second

$n = 3.056 \times 10^{19}$

MA1 – Correct answer with explanation of why 3*n* (because there are 3 wavelengths), deduct 0.5 pts for no explanation offered.

Answer = $3n = 9.17 \times 10^{19}$ (Penalise holistically for wrong value due to truncation error in second M1 mark)