1. (penalty for sig fig error = 1 mark per question)

(a) neutron: relative mass = 1 relative charge = 0 (not ‘neutral’)

electron: relative mass = \(1/1800\) → negligible or
\(5.56 \times 10^{-4}\) → 0 relative charge = –1

(b) \(^{17}\text{O}/^{17}\text{O}\) mass number (Do not accept 17.0)

- oxygen symbol ‘O’
- (if ‘oxygen’ + ‘mass number = 17(1)’)
- (if ‘oxygen’ + ‘mass number = 17(0)’)
- (if at \(N_0\) given but ≠ 8, treat as ‘con’ for M2)
- (if lp on Be, diagram = 0)
- (ignore bond angles)
- (not dot and cross diagrams)

2. (a) (i) \(p + n\) / number of nucleons (accept protons and neutrons)

Incorrect reference to electrons = contradiction

(ii) Mean / average mass of a molecule/entity/formula

\(1/12\)th mass of atom of \(^{12}\text{C}\)

[Not \(1/12\)th mass of molecule of \(^{12}\text{C}\)] (mark independently)

OR Mass of 1 mole of molecules/entities

\(1/12\)th mass of 1 mole of \(^{12}\text{C}\)

OR Average mass of a molecule/entity

Relative to the mass of a \(^{12}\text{C}\) atom taken as 12 / 12,000

(Mean/average = stated or explained)

(mass = stated or explained)

(Penalise ‘weight’ once only)

(Ignore ‘average’ mass of \(^{12}\text{C}\))

(Do not allow ‘mass of average molecule’)

(b) (i) \(2s^22p^63s^23p^64s^13d^{10}\) (accept 3d\(^9\)4s\(^2\))

(accept subscripts or caps)

[Penalise missing shell numbers]

(ii) d / D [NOT 3d/ ‘transition element’]

(iii) 36 [NOT 36.0]

(c) (i) More \(^{63}\text{Cu}\) atoms than \(^{65}\text{Cu}\) atoms

(Idea of more abundant \(^{63}\text{Cu}\) isotope - NOT just reference to peak heights)

(ii) Electron from electron gun / high speed electron / high energy electron

(accept electron gun fired at)

[NOT ‘bombarded with electrons’]

knock electron off (Cu atom) / idea of loss of e\(^-\) / appropriate equation

(Mark independently)
(iii) $^{63}\text{Cu}^{2+}$ or equivalent \([\text{NOT 63.0 - penalise this error once only}]\)

$m/z = 63/2 (=31.5)$ or equivalent

More energy needed to remove second electron OR

$^{63}\text{Cu}^{2+}$ statistically less likely to remove second electron

(Idea that not many $^{63}\text{Cu}^{2+}$ ions formed OR explains why few are formed e.g. more energy needed)

*If $^{63}\text{Cu}$ not given, can only award M2 & M3*

Notes on [If 65 used, lose M1 and M2]

(c) (iii) [If mass number missing from identity but appears in explanation, penalise M1 but allow M2 if earned]

[12]

3. (a) (i) (atoms with the) same number of protons / same atomic number / atoms of the same element; \((molecules = contradiction)\)

But different number of neutrons / different mass number; \((not different atomic mass or A_r)\)

(ii) detected by: +ve ions collide with / are directed or deflected to / are collected at the detector; causing current to flow / detected electrically / idea of electricity or voltage generated; \((not ‘charge produced’ or ‘detected electronically’)\)

abundance measured: idea that current depends on abundance/number of ions hitting detector;

(b) (i) mean /average mass of an atom / all the isotopes:

$1/12^{th}$ mass of atom of $^{12}\text{C}$ ;

\((mark independently)\)

OR

mass of 1 mole of atoms (of an element):

$1/12^{th}$ mass of 1 mole of $^{12}\text{C}$;  

OR

average mass of a molecule/entity; relative to the mass of a $^{12}\text{C}$ atom taken as 12 / 12.000; \((penalise ‘weight’ once only)\)

\((ignore ‘average’ mass of $^{12}\text{C}$)\)

\((do not allow ‘mass of average atom’)\)

(ii) \[ \frac{(54 \times 5.8) + (56 \times 91.6) + (57 \times 2.6)}{100} ; \]

\[ = 55.9 ; \]

(c) (i) $1s^2 2s^2 2p^6 3s^2 3p^6$;

\((accept subscripts or caps; ignore 4s^0) (penalise missing shell)\)
(ii) highest energy level / last sub-shell to be filled / is (3)d;

OR

outermost electrons in the d sub-shell/orbital;
(not incomplete d sub-shell)
(not valance electron in d sub-shell)

(iii) no difference;

same e− arrangement / same number of e− / same valence e−.

OR

same chemical properties;

OR

chemical properties determined by electrons;

(M2 tied to correct answer for M1)

4. (a)

<table>
<thead>
<tr>
<th>Particle</th>
<th>Relative charge</th>
<th>Relative mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>+1 or 1+</td>
<td>1</td>
</tr>
<tr>
<td>Neutron</td>
<td>0 or no charge/neutral/zero</td>
<td>1 (not −1)</td>
</tr>
<tr>
<td>Electron</td>
<td>−1 or 1−</td>
<td>1/1800 to 1/2000</td>
</tr>
</tbody>
</table>

if ‘g’ in mass column - wrong
penalise once

or negligible
or zero
or 5.0 × 10^{-4} to 5.6 × 10^{-4}

(b) 38_{18} Ar

Allow numbers before or after Ar

(1)(1)

3

(c) S: 1s^{2} 2s^{2} 2p^{6} 3s^{2} 3p^{4} (1)

Allow upper case letters

S^{2−}: 1s^{2} 2s^{2} 2p^{6} 3s^{2} 3p^{6} (1)

If use subscript penalise once

(1)

2
(d) **Block:** p (1)
*Explanation:* Highest energy or outer orbital is (3) p
OR outer electron, valency electron in (3) p
NOT 2p etc.

5. (a) number of protons in one atom or nucleus (1)
Allow protons & electrons
do not allow protons + electrons or electrons

(b) $^{23}_{11}$ Na (1)
OR Na$^{23}_{11}$ or Na (1) + unambiguous statement of mass no. and atomic no.

(c) 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^1$ (1)
Allow Ne 3s$^2$ 3p$^1$

(d) 14 (1)

(e) average mass of an atom (or isotope) (1) $\times$ 12 (1)
Reference to mass number not mass C.E. = 0
OR stated in moles
OR compared with 1/12 of a $^{12}$C atom or relative to $^{12}$C when taken as 12

(f) (i) electron gun (1)

(ii) (particles must be charged) (ions) before attraction to a charged plate (or electric field) (1)
(or only ions can be attracted or accelerated by an electric field)
or converse; if not charge not attracted to electric field

(iii) magnetic field (or magnet) (1)

(iv) magnetic field (1) (accelerating potential or strength of magnet)
allow magnet
(g) (i) \[
\frac{24.0 \times 64.2 + 25.0 \times 20.3 + 26.0 \times 15.5}{100(1)}
\]
(1) mark for any m/z × relative abundance

If numerator is correct but 100 has A.E. conseq A.E. -1
If A.E. on 100 allow conseq correct answer provided numerator is correct

= 24.5 (1)

Allow 24.5 to 24.52
ignore units

(ii) magnesium (1) (or Mg) (allow conseq on wrong Ar)

(iii) abundance of isotopes is different (1) (or different isotopes)

6. (a) (i) A = electron, B = neutron and C = proton all correctly identified (1)
do not give if any reference to cation / anion 1

(ii) neutron / n⁰ / B has no charge and so is undeflected (1)
proton / p⁺ / C and electron / e⁻ / A attracted to –ve and +ve plates respectively (1)
correct direction and shape for one particle gains one mark
mass p > mass e⁻ so deflected less / mass C > mass A so deflected less (1)
allow this mark for valid difference in property and explanation of shape
allow reference to other particles here 3

(b) (i) to produce high speed electrons / stream of electrons or to fire electrons or
to bombard with electrons or is an electron gun (1)
which remove electrons from species cause formation of positive ions
not to ionise (1) 2

(ii) to accelerate / speed up positive ions / ions / fragments (1)
not electrons atoms / molecule / sample
allow particles / molecular ion
to deflect / bend ions / ion stream (not to provide magnetic field)
or separate ions accordingly to mass / charge ratio (1)
to detect positive ions / ions / particles / fragments / molecular ion (1)
allow purpose of specific detector or ion detector
not just detector or collector
allow second and third marks if wrong type of particle given 3 [11]
7. (a) number of protons (1)
(b) different number of neutrons (1)
\(\text{they are ‘isotopes’ – not enough for the mark}\) (1)
(c) (i) mass spectrometer (1)
allow spectroscope
(ii) (or average)
\[
\frac{\text{mean mass of an atom}}{\text{mass}} \times 12 \quad (1)
\]
or
\[
\frac{\text{mass of 1 mol of atoms}}{\text{mass of 1 mol of } ^{12}\text{C atoms}} \times 12 \quad (1)
\]
or mean mass of an atom (1)
or compared with \{an atom of \(^{12}\text{C}\) taken as 12
\(\frac{1}{12}\) of a \(^{12}\text{C}\) atom
\(If\ molecule,\ element\ or\ entity\ instead\ of\ ‘atom’\ lose\ 1\ mark\) (1)
(iii) \[
\frac{82 \times 12 + 83 \times 12 + (84 \times 50) + (86 \times 26)}{100} \quad (1) = 84.16 \quad (1)
\]
allow 84.1 to 84.2 ignore units (5)
(d) outer electron in Rb is in 5\(^{\text{th}}\) shell (or additional shell) (1)
further away (or more shielded) from nucleus (1)
\(\text{mark independently but if there is contradiction – no marks}\) (2) [9]
8.  (a) (i) the number of protons and neutrons / number of nucleons in the nucleus / atom 

    not in an element 

(ii) weighted average / mean mass of the isotopes or of atoms not of an element / average mass in an isotopic mixture / average mass of all naturally occurring isotopes (1) 

measured on the $^{12}$C scale / relative to $\frac{1}{12}$ th the mass of one atom of the $^{12}$C isotope (1) 

    independent of first mark 

(b) $\frac{32 \times 95 + 33 \times 0.8 + 34 \times 4.2}{100}$ (1) 

    32.1 (ignore units) – answer only gets both marks (1) 

9.  (a) Number of protons & number of neutrons (1) 

(b) $^{17}_8$O (1) 

(c) (i) 

<table>
<thead>
<tr>
<th>Particle</th>
<th>proton</th>
<th>neutron</th>
<th>Electron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass /g</td>
<td>$1.6725 \times 10^{-24}$</td>
<td>$1.6748 \times 10^{-24}$</td>
<td>$0.0009 \times 10^{-24}$</td>
</tr>
<tr>
<td>Relative charge</td>
<td>$+1$</td>
<td>$0$</td>
<td>$-1$</td>
</tr>
</tbody>
</table>

(ii) $1.6734 \times 10^{-24}$ g (1) 

(iii) 1.0078 g (1) 

(iv) other isotopes present (1) 

(d) (i) electric field (or charged plate) (1) 

(ii) magnet (1) 

(iii) different isotopes (1) 

(or different masses) 

(iv) accelerate ions more 

(or reduce magnetic field) (1) 

(v) $Measurement 1 \quad \frac{m}{z}$ (1) 

$Measurement 2 \quad \text{abundance}$ (1)
10. (a) electron gun
(b) accelerated
(c) speed
(d) \[
\frac{82 \times 1 + 83 \times 1 + 84 \times 5 + 86 \times 2}{9}
\]
\[= 84.1\]

11. (a) Atoms/isotopes/particles/species with the same (number of) protons and different (number of) neutrons

(b) \[\frac{37}{17} \text{Cl}\]

(c) (i) \[2s^22p^63s^23p^63d^{10}4s^24p^2\]

(ii) \[A_r = \frac{(70 \times 24.4) + (72 \times 32.4) + (74 \times 43.2)}{100}\]

\[= 72.4\]

(d) 72 Ge²⁺ only

Same m/z as 36S⁺
12. (a) aluminium: \(1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^1\) (1)
    vanadium: \(1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \ 3d^3\) or \(3d^3 \ 4s^2\) (1)

(b) s-block

13. (a) \(^{34}\text{S}\) (1)

(b) \(1.65 \times 10^{-24}\) (1)

\[
\frac{2.158 \times 10^{-23}}{1.993 \times 10^{-23}} \times 12 = 12.99\]

or \(6.023 \times 10^{23} \times 2.158 \times 10^{-23} = 12.998\)

any use of \(^{12}\text{C}\) & \(^{13}\text{C}\) (1)

\[
\frac{12 \times 98.9}{100} + \frac{13 \times 11}{100} = 12.01\]

14. (a) Electron gun (1)
    knocks out electron(s) from the particle (1)

(b) Reason 1 acceleration (1)
    Reason 2 deflection (1)

(c) \(\frac{20}{100} \times 10 + \frac{80}{100} \times 11\) (1)

\[= 10.8\]

15. (a) \((1s^22s^2) \ 2p^63s^23p^2\) (1)

(b) \(\text{Si}(g) \rightarrow \text{Si}^+(g) + e^-\) balanced (1)
    \(\text{Si}^+(g) \rightarrow \text{Si}^{2+}(g) + e^-\) balanced (1)

correct state symbols in both equations (allow even if not balanced) (1)
16. (a) proportion / ratio / frequency / percentage / abundance of each isotope / different type of atom / specific atom not amount unless relative amount compared to total amount (1) present in the (natural) isotopic mixture / sample of the element / compound containing the element (1) reference to relative atomic mass worth zero marks 2

(b) \((0.0802 \times 46) + (0.0731 \times 47) + (0.7381 \times 48) + (0.0554 \times 49) + (0.0532 \times 50)\) (1) 
\(= 47.9\) (ignore units) (1) 2

17. (a) \(1s^2\) \(2s^2\)\(2p^6\) (accept capitals and subscripts) 1

(b) ‘s’ block (not a specific ‘s’ orbital – e.g. 2s) 1

(c) \(\text{Mg}^{2+}\) ion smaller than Ne atom / \(\text{Mg}^{2+}\) e– closer to nucleus \((\text{Not ‘atomic’ radius fo } \text{Mg}^{2+})\)
\(\text{Mg}^{2+}\) has more protons than Ne / higher nuclear charge or \(\text{e}^–\) is removed from a charged \(\text{Mg}^{2+}\) ion / neutral neon atom \((\text{accept converse arguments})\)
\(\text{If used ‘It’ or Mg/magnesium/Mg}^{3+}\) etc. & 2 correct reasons, allow (1)) 1

(d) (i) trend: increases \((\text{if ‘decreases’, CE = 0/3})\)
Expln: more protons / increased proton number / increased nuclear charge \((\text{NOT increased atomic number})\)
same shell / same shielding / smaller size 1

(ii) \textbf{QoL} reference to the \(\text{e}^–\) pair in the 3p sub-level \((\text{penalise if wrong shell, e.g. ‘2p’, quoted})\)
repulsion between the \(\text{e}^–\) in this \(\text{e}^–\) pair \((\text{if not stated, ‘e}^–\text{ pair’ must be clearly implied})\)
\(\text{mark M4 and M5 separately})\) 1

18. (a) Spin (1) 1

(b) Further from nucleus (1)
(or more shielded) 1

(c) Energy to remove 1 electron (1) \(\text{(or 1 mol electrons)}\)
from a \textit{gaseous} atom (1) \(\text{(or molecule or 1 mol of atoms/molecules)}\) 2
(d) Be’s outer electron is in an s (2s) orbital (1)
B’s outer electron is in a p (2p) orbital (1)
B’s outer electron is higher in energy (1)

(e) Electron is not shielded from nucleus (1)

19.

(a) (i) increases;
(ii) lower than expected / lower than Mg / less energy needed to ionise; e\(^–\) removed from (3)p sub-level;
(‘e\(^–\) removed’ may be implied)
of higher energy / further away from nucleus / shielded by 3s e\(^–\)s;

(b) Al\(^+(g)\) → Al\(^{2+}(g)\) + e\(^–\);

20.

(a) Na\((g)\) → Na\(^+(g)\) + e\(^–\)
OR Na\((g)\) + e\(^–\) → Na\(^+(g)\) + 2e\(^–\)
(-) on electron not essential
equation (1)
state symbols (1)
Ignore state symbols on electrons

(b) Trend : Increases (1)
Explanation : Increased nuclear charge or proton number (1)
Stronger attraction (between nucleus and (outer) e\(^–\)) (1)
Trend wrong
Allow M2 only if M3 correct (con)

(c) How values deviate from trend: (both values) too low (1)
Explanation for Al: e\(^–\) removed from (3) p (1)
e\(^–\) or orbital is higher in energy level or better
shielded than (3)s
or p electron is shielded by 3s electrons (1)
Allow e\(^–\) is further away
Mark independently

Explanation for S: e\(^–\) removed from (3)p electron pair (1)
repulsion between paired e\(^–\) (reduces energy required) (1)
Mark separately
If deviation wrong allow M2 and M4
If M3 and / or M5 right 0 (con)
If used ‘d’ rather than ‘p’ orbital - lose M2 + M4 but may get M3, M5 (explanation marks)
21. (a) Heat / enthalpy / energy for removal of one electron (1) from a gaseous atom (1) can score in an equation  

must have first mark to score the second

(b) (i) 2 (1) 
(ii) Two elements (or Na / Mg) before the drop (in energy) to Al (1) 
(iii) ionisation energy of Al < that for Mg (1) 
(iv) fall in energy from P to S (1)  
or discontinuity in trend

From Al to P there are 3 additional electrons (1)  
or three elements

For second mark idea of block of 3 elements 

22. Number of protons increases (1) 
Electrons in same shell (1) (or same shielding) 2

23. (a)

(b) Ne $\rightarrow$ Ne$^+$ + e$^-$ (1) 1

(c) Explanation for neon Neon’s electron is in a lower (2p) shell (1) 

attracted more strongly to (or less shielded from) the nucleus (1)  

Explanation for magnesium more protons (1) 

electrons in same shell  
or similar shielding (1) 4
(d) Als outer electron is in a 3p sub-shell (1)
higher in energy than 3s in Magnesium (1) 2

24. increased nuclear charge / nuclear attraction number of protons  (1)
same shielding / electrons added to same or outer shell / increase in number  (1)
of electrons in outer shell
therefore (outer) electrons attracted / pulled in more strongly or more closely  (1)
‘increased effective nuclear charge’ worth 2 marks

25. (a) Proton: mass 1, charge +1 (1)
Neutron: mass 1, charge 0 (1)
Electron 1/1840, charge -1 (1)
Allow mass = 0, or negligible, or 1/1800 to 1/2000

Isotopes have the same number of protons (1)
OR atomic number

different number of neutrons (1)

Isotopes have the same electronic configuration (1)
OR same number of electrons

Chemical properties depend on electrons 7

(b) \[
\frac{\text{average mass of an atom/isotopes}}{\text{mass of 1 atom of } ^{12}\text{C}} \times 12 \quad (1)
\]
OR \[
\frac{\text{mass of 1 mol of atoms}}{\text{mass of 1 atom of } ^{12}\text{C}} \times 12 \quad \text{or in words}
\]

Spectrum gives (relative) abundance (1)
OR % or amount

And \( m/z \) (1)
Multiply \( m/z \) by relative abundance for each isotope (1)
Allow instead of \( m/z \) mass no, \( A_r \) or actual value from example

Sum these values (1)
Divide by the sum of the relative abundances (1)
only award this mark if previous 2 given
Max 2 if e.g. has only 2 isotopes 7
26. (a) Ionisation (1)
High speed or high energy electrons or electron gun (1)
   NOT bombard
   NOT beam or stream of electrons

Knocks out (outer) electron (1)

Forming positive ion - could be from Ti → Ti⁺ + e⁻ (1)
   Accept + ion later in question to clarify charge of ion
   Ti + e⁻ → Ti⁺ + 2 e⁻ worth 2 marks
   Ignore state symbols

Acceleration (1)

By electric field or attraction to negative plate or electrostatic attraction (1)
   NOT repelled by + plate
   Allow passed through positive & negative plates / oppositely charged plates
   Not just charged plates

Deflection (1)

By magnetic field or magnet or electromagnet (1)

Detection (1)

Idea that ions collected at detector and generate current (1)

Both ions have the same m / z value (of 24) or valid arguments in terms of the doubled charge on ⁴⁸Ti⁺ exactly counteracting its doubled mass (1)

Deflected equally (so detected together) or deflection dependent on m / z value (1)
   Can't get this from previous section

(b) Differ in mass number or number of neutrons (1)

Same proton / atomic number (1)
   Ignore reference to electrons here

Isotopes have the same chemical properties (1)

because all have the same electron configuration or number of electrons or same number of valence electrons (so no chemical difference) (1)

   This mark is tied to the above mark or near miss [similar etc] in M3
(c) Mean mass of an atom or (isotope) (1) [NOT mass of average atom]
Relative to 1/12 mass of 12C atom atc. Or to 12C taken as 12.000 or exactly 12 (1)

**Isotope can be accepted**

\[
\text{mean (average) mass of an atom} = \frac{\text{mass of an atom of } ^{12}\text{C}}{12} (1) \times 12 (1)
\]

\[
\text{mass of 1 mol of atoms} \times \frac{\text{mass of 1 mol of } ^{12}\text{C}}{12} (1) \times 12 (1)
\]

\[
A_r = (46 \times 0.0802) + (47 \times 0.0731) + (48 \times 0.7381) + (49 \times 0.0554) + (50 \times 0.0532) (1)
\]

\[
= 47.93 \text{ answer to 2 d.p} (1)
\]

47.92 is acceptable

Must be 5 sets of values

Ignore transcription errors BUT DON'T ignore missing 100 C.E.

If missing isotope C.E.

27. (a) protons mass +1 charge + (1)
    neutrons mass +1 charge zero (1)
    electrons mass ~ zero (or<1/1800), charge – (1)

    nitrogen –14 has a nucleus with 7 protons and 7 neutrons (1)
    surrounded by electrons in shells (or orbitals) (or 2,5) (1)
    with configuration 1s^2 2s^2 2p^3 (scores last 2 marks) (1)

(b) isotopes have the same atomic number (or same number of protons or same element) (1)
    but different number of neutrons (or mass number) (1)

(c) fraction of each component is rel. int./44 (1)
    [the mark is for 44, if 42 max 1]
    relative atomic mass
    \[
    = 1 \times 80/44 + 5 \times 82/44 + 5 \times 83/44 + 25 \times 84/44 + 8 \times 86/44 (1)
    \]
    \[
    = 83.9 (1)
    \]
    Krypton (1)

28. (a) Mean (average) mass of an atom / all the isotopes or 1
    1/12^{th} mass of atom of 12C

    Mass of 1 mole of atoms of an element or
    1/12^{th} mass of 1 mole of 12C
    average mass of an atom / all the isotopes

    Relative to the mass of a 12C atom taken as exactly 12 / 12.000

    (penalise ‘weight’ once only) (ignore ‘average’ mass of 12C)
    (not ‘mass of average atom’)

    Mill Hill High School 15
(b) \[ A_2 = (64 \times 0.389) + (66 \times 0.278) + (67 \times 0.147) + (68 \times 0.186) \]
\[ = 65.7 \]

(mark M2 conseq on transcription error or incorrect addition of %) 1

identity: zinc / Zn 1

(Conseq on \( A_2 \) but only if their \( A_2 \) is within range of Periodic Table) 1

(c) electron gun (fires) electrons or high speed/energy electrons 1

(not just 'bombarded by electrons' or 'bombarded by electron gun')

knocks off e\(^{-}\) from Q 1

(may be earned from a real or generic equation)

Reasons: to allow ions to be: 1
accelerated (by an electric field) 1
deflected (by a magnet/magnetic field) 1
detected / description of current formed at the detector/sensor 1

(accept in any order) 1
(allow clear descriptions of 'accelerated', 'deflected', 'detected') 1

29. general increase across period (1)

\( \text{can score this and points 4, 7 on graph} \)

because number of protons (or nuclear charge) increases (1)

but electrons in same shell (or similar shielding) (1)

fall from Mg to Al (1)

Al’s outer electron is in a \( p \) orbital (1)

higher in energy than \( s \) electron in Mg (1)

\( \text{if wrong period –1} \)

fall from \( P \) to \( S \) (1)

two of the \( p \) electrons in \( S \) are paired (or in same orbital) (1)