1.  
   (a)  
      (i)  **Atomic number**: number of protons (in the nucleus)  
           **Mass number**: [Total/sum of the] numbers of protons plus/and neutrons  
          2
      
      (ii)  $Na^+$ or $^{23}_{11}Na^+$ or a sodium ion  
          1
(b)  
      (i)  $(^{79}\text{Br}^{81}\text{Br})^+$ or $(^{79}\text{Br}^{81}\text{Br})^+$  
          1
      (ii)  Some working or justification  
           50:50 or equivalent  
           e.g. Because the two peaks at 158 and 162 are the same height  
                the relative abundance of each must be 50%  
          2
(c)  
      The heat /energy/ enthalpy change/ released per mole of electrons  
      for addition to 1 mol of gaseous(bromine) atoms  
      $\text{Br(g)} + e^- \rightarrow \text{Br}^-(g)$  
      3  
      The word gaseous may be omitted provided the state symbol is present on both sides of the equation / vice versa
(d)  
      (i)  The heat /energy/ enthalpy change/needed per mol of electrons  
      for removal from 1 mol of gaseous(neon) atoms  
      The equation is not asked for but can be used to score the second mark above.  
      2
      
      $\text{Ne(g)} - e^- \rightarrow \text{Ne}^+(g)$
      (ii)  (The first ionisation energy increases as) the nuclear charge increases  
            (Inner shell) shielding remains the same (as nuclear charge increases)/ electrons removed from same energy level/shell  
            2
      (iii)  there is less inner shell shielding in Ne  
            Although there is an increase in the nuclear charge from Ne to Ar  
            OR  
            atomic radius for Ne is smaller than for Ar/ the outer (2p) electron in Ne is closer to the nucleus than the (3p) electron in Ar  
            2

2.  
   (a)  
      $H  
      \begin{array}{c|c}
          1 & \text{C} \\
          1.1 & 88.9 \\
          \hline
          11.1 & 12 \\
      \end{array}$  
      1
      $= 11.1$  
      $= 7.4$  
      1.5  
      1  
      Empirical formula $C_2H_3$  
      3
(b)  
      HI has more electrons  
      has greater induced–dipole–induced dipole / vdW forces  
      2
(c)  (i)  *pyramidal*

\[
\begin{array}{c}
\text{H} \\
\text{P} \\
\text{H} \\
\text{H}
\end{array}
\]

Need to show evidence of three dimensional or state it is pyramidal with two dimensional diagram (1)
3 bond pairs and 1 lone pair to get as far apart as possible (1)  
2

(ii)  *tetrahedral*

\[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{Al} \\
\text{H}
\end{array}
\]

Need to show evidence of three dimensional or state it is tetrahedral with two dimensional diagram (1)
4 bond pairs around aluminium as far apart as possible (1)  
2

(d)  Amount of phosphine  
\[= \frac{8.0}{24000} \] (1)  
\[= 3.33 \times 10^{-4} \text{ mol} \]
Number of molecules of phosphine  
\[= 6.0 \times 10^{23} \times 3.33 \times 10^{-4} \] (1)  
\[= 2.0 \times 10^{20} \]

[11]

3.  (a)  (i)  The enthalpy / heat / heat energy change / released when 1 mol of benzene is formed (1) from its elements (1) under standard conditions  
2
(ii)  The enthalpy / heat / heat energy change when 1 mol of benzene burns (1) in excess oxygen / burns to form carbon dioxide plus water / is completely oxidized under standard conditions (1)
The second mark is not awarded if standard conditions are not mentioned in part (i) or (ii).  
2

(b)  
\[
\begin{array}{c}
6\text{C} + 3\text{H}_2 \\
\text{C}_6\text{H}_6 \\
6\text{CO}_2 + 3\text{H}_2\text{O}
\end{array}
\]

\[\Delta\text{H}1 \]  
\[\Delta\text{H}2 \]

For correct cycle shown (1) or equivalent equations
\[\Delta\text{H}1 = 6 \times (-394) + 3 \times (-286) = -3222 \text{ kJ} \] (1) for either showing calculation or answer
\[\Delta\text{Hf} = -3222 - (-3273) = +51 \text{ kJ mol}^{-1} \] (1)  
3
(c) Benzene has \( \pi \) electrons delocalised (1) Therefore bond energy NOT that of C–C or C=C

\[
\begin{array}{c}
\text{Energy} \\
\text{localised (1)} \\
\text{++215} \\
\text{6C(s) + 3H}_2(g) \\
\text{Delocalised (1) –consequential} \\
\text{++51}
\end{array}
\]

(d) (i) \( \text{rate} = k[\text{benzene}][\text{bromine}] \)

(ii) \( \text{rate would be decreased (1)} \)

\( \text{E}_a \) of rate determining step \( \text{or the idea of it) would be increased} \) (1)

4.

(a) (i) electron configuration or \( 3d^64s^2 \) or \( 4s^2 \)

or number of outer electrons

(ii) 26 protons, 26 electrons, 30 neutrons

all 3 (2) any 2 (1)

(iii) atoms (of same element) with same number of

protons or same atomic number

different number of neutrons or mass number

(b) (i) A ionisation not vaporisation

B acceleration

C deflection

D detection

(ii) \( \frac{(5.8 \times 54) + (91.6 \times 56) + (2.2 \times 57) + (0.33 \times 58)}{100} \)

= 55.87

[11]
5. (a) (i) number of protons (in the nucleus)/ proton number (1)

*not* 'number of electrons’ or ‘number of protons in an element’ (1)

(ii) Electronic configuration differs from previous element by an electron in a d (sub)
shell or orbital / d-shell is filling / d electron is last electron (1)

Allow outer electron is d / highest energy electron is d

(iii) Forms at least one ion/compound with partially full / incomplete d sub shell (1)

1

(b) \[1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \ 3d^5 \ or \ 3d^54s^2 \ (1)\]

(c) (i) The heat/energy/enthalpy change needed to remove one mole of electrons (1)
from (1 mole) of gaseous (chlorine) atoms (1)

Correct equation i.e. \( \text{Cl}(g) \rightarrow \text{Cl}^+(g) + e^- \) can score second mark. 2

(ii) Increasing slopes (1)
Jump after 7 (1)
Jump after 15 (1)

Ignore small jumps in the correct places. The points do not need to be joined. 3

(d) There are several way of doing this calculation; the following is one way. All other valid
ways score full marks
43.7/55 = 0.795  \[56.3/35.5 = 1.59 \ (1)\]
0.795/0.795 = 1 \[1.59/0.795 = 2 \ (1)\]
MnCl\(_2\) (1) This is a stand alone mark
or
MnCl\(_2\) and some correct working (3)

Note:
If a candidate gets a formula MnCl\(_x\) where \( x \) is between 2 and 7 because they have made a chemical error, they can score a maximum of 1 mark. If the error is mathematical they can score a maximum of 2 marks

3

[12]

6. (a) (i) Fast/high energy/fired/bombard/electrons (electron gun) strike sample atoms

• Knocking out/ remove electron from sample atom 2

(ii) Electric field/charged plates/negative plates 1

2
(b) (i) \( ^{65}\text{Cu}^+ \)

(ii) (2)(different) isotopes

(iii) \((63 \times 69.1) + (65 \times 30.9) \) divided by \((69.1 + 30.9)\) \((1)\)

\[= \frac{63.6 \times 63.62}{63.618} \]  

7. (a) (i) Number of protons + number of neutrons \((1)\)

(ii) (weighted) average / mean mass of one atom \((1)\)

relative to one twelfth the mass of carbon-1 2 (atom) / on a scale in which \(^{12}\text{C} = 12 \) \((1)\)

(iii) atoms with same atomic no/ same no of protons/ same element \((1)\)

but different numbers of neutrons / mass number \((1)\)

(b) \((24 \times 0.7860) + (25 \times 0.1011) + (26 \times 0.1129) \) \((1)\)

24.33 \((1)\)

8. (a) (Heat) energy / enthalpy change needed/required per mole \((1)\)

to remove an electron \((1)\)

from an atom of magnesium in the gas phase \((1)\)

For three marks to be awarded there must be some reference to magnesium in the written answer or in an equation. \((3)\)

(b) (i) Two big jumps show three/new/different shells present \((1)\)

2 electrons with lowest I.E. in outer shell / first two electrons in outer shell / idea of order of removal \((1)\)

then 8 then 2 / shows it is 2.8.2 \((1)\)

Reference to s and p type electrons loses final mark because data does not show this.

The use of orbital/sub shell rather than shell should be penalised once only. \((3)\)

(c) (i) \(1^s2^s2^p^63^s^2 \) \((1)\)

(ii) Same number of electrons (in all magnesium isotopes) \((1)\)

\textbf{outer} electron structure determines chemical properties \((1)\)

9. (a) ![Diagram](image)

(1)
Must show all the outer electrons around the chlorine
Do not have to be • and +

(b) (i)  \[ \text{Cl} \quad \text{B} \quad \text{Cl} \quad (\text{I}) \]

(ii) The (three) bonding (electron) pairs (I)
    repel as far apart as possible / position of minimum repulsion
    (I) not stand alone
    not just equal repulsion

(c) (i) Power (of an atom) to attract (the pair of) electrons (I)
    in a covalent bond / bonding pair (I)

(ii) Bonds arranged symmetrically /molecule symmetrical /bond
    polarities directional/ are vectors (I)
    Bond polarities cancel (I)
    Could be shown as a diagram

Note:
The answer to (b) is consequential on the answer to (a) in the
following situation
If the candidate puts a lone pair of electrons on the boron
• the shape mark can be given for a clear, 3-D diagram of a
  molecule with the same shape as ammonia
• the explanation will need to refer to both bond and lone
  pairs of electrons

10. (a) Proton + 1 (I)
    Electron 1/1800 → 1/2000 or ‘negligible’ (I)
    Neutron charge 0 / no charge (I)
    Correct p n e in both C and H (I)
    Notes there are 4 H (I)
    Correct summation i.e 10p, 10e, 6n (I)
    If no or inadequate working 1 mark for 10 p & 10 e
    1 mark for 6 n.
(c) \((1s^2)2s^22p^63s^23p^5\) (I) 1

(d) \(^{37}\text{Cl}^-
\)
charge(stand alone) (I) 2
\(37\) (I)
if incorrect number of protons / mass number
shown max 1 for charge 2

(e) (i) \(\text{S(g)} + e^- \rightarrow \text{S}^-(g)\)
species and charges (I) 2
state symbols in part (i) and (ii) equations (I)

(ii) \(\text{S(g)} \rightarrow \text{S}^+(g) + e^-\)
or
\(\text{S(g)} - e^- \rightarrow \text{S}^+(g)\) (I) 1
Species and charge (I)
No need to show negative charge on electron.
*If use ‘X’ in place of ‘S’ penalise once only*

(f) Chlorine nucleus has greater charge / is more positive / has greater number of protons (I)
outer electron / electron being removed, is in same shell / has same shielding (I) 2

11. (a) (i) \((1s^2)2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^6\) (I) 1

(ii) \(7\) (I) 1

(b) (i) \(\text{Ca} + \text{Cl}_2 \rightarrow \text{CaCl}_2\) (I) 1

(ii) Ionic (I) 1

(iii) \[
\text{Cl}^+ \ [\text{Ca}]^{2-} \ [\text{Cl}^-]
\]
* 1 mark for correct number of electrons on each ion (I)*
1 mark for correct charges on each ion (I)
1 mark for correct ratio of ions (I) 3

[7]

12. (a) Protons 3 (I)
Neutrons 4 (I)
Electrons 2 (I) 3
(b) Relative atomic mass
\[
\frac{(6.02 \times 7.39) + (7.02 \times 92.61)}{100} \quad (1)
\]
6.95 (must be three s.f.) (1)

(c) • Dip Pt / nichrome wire in solid and place in hot/blue flame (1)
• Na salt gives yellow colour (1)
Li salt give deep / magenta red / crimson colour (1)

13. (a) • Magnesium ions are arranged in a regular lattice (1)
• surrounded by a sea of / cloud of / delocalised electrons (1)
which can move through the solid when a potential is applied (1)

(b) • At room temperature the ions are in a fixed position / in a lattice (1)
• as heat applied the ions vibrate more (1)
eventually ions have enough energy to overcome electrostatic attraction (1)
ions break free are able to move as solid melts (1)

(c) • Solid has ions in fixed sites / cannot move (1)
• molten has ions free to move and carry current to electrodes (1)

14. (a) (i) • Energy / enthalpy change per mole (1)
• required to remove an electron (1)
from / mole of gaseous atoms (1)

(ii) • The nuclear charge on K is greater than on Na (1)
• the outer electron is further from the nucleus (1)
but there is more shielding around K than Na (1)

(b) (i) \( \frac{4.56}{71} (1) = 0.0642 \text{ (1) mol} \)
(ii) Answer from (i) – 2 (1) = 0.0321 mol
(iii) Answer from (ii) \( \times 24 \) (1) 0.771 dm³
(iv) Answer from (iii) \( \times 3/2 \) (1) 1.16 dm³

15. (a) (i) \( (46 \times 8 + 47 \times 7.3 + 48 \times 74 + 49 \times 5.5 + 50 \times 5.2) \div 100 = 47.926 \)
\( = 47.9 \)

Method (1)
Correct answer to three significant figures (1)
(ii) mass spectrometer  1

(b) (i)  \(1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \ 3d^2 \ OR \ 3d^2 \ 4s^2 \ (1)\)  2

(ii) Transition metals /elements OR d block  1

(c) (i) reduction or redox  1

(ii) \(940 - 2 \times 110 = +720 \text{ kJ mol}^{-1}\)

Method (1)  
Value (1)  
Sign and units (1)  3

(iii) Hess / Law of Conservation of Energy First Law of Thermodynamics  1

(iv) Carbon monoxide / CO is produced (1)  
which is toxic / poisonous (1)  2

[13]

16. (a) (i) Description of asymmetry of electron/charge cloud hence attractive forces between neighbouring induced dipoles  1

(ii) NCl\(_3\) / chlorine because more electrons  1

(iii) NF\(_3\) because F more electronegative (than Cl)  1

(iv) Van der Waals forces more significant/greater than permanent dipole-dipole interactions  1
(b)  

(i)  
\[ N(g) + 3F(g) \text{ in top right-hand box} \]
\[ \frac{1}{2} \, N_2(g) + 1 \, \frac{1}{2} \, F_2(g) \text{ in lower box.} \]  

(ii)  
\[ -125 \, \text{(kJ mol}^{-1}) \]
\[ \text{(1)} \]
\[ 473 + (3 \times 79) \]
\[ = (+) \, 710 \, \text{(kJ mol}^{-1}) \]
\[ \text{ACCEPT 710 alone} \]
\[ \text{(1)} \]

\text{Arrows in correct directions and labelled with correct data} \quad 2

(iii)  
\[ \Delta H_{\text{at}}^\circ \text{ for } [\text{NF}_3(g)] \rightarrow N(g) + 3F(g) = 710 - (-125) = (+) \, 835 \, \text{(kJ mol}^{-1}) \] \text{ (1)}

\[ E(\text{N} - \text{F}) = \frac{835}{3} = (+) \, 278 \, \text{kJ mol}^{-1} \] \text{ (1)}

\text{Penalise 4 or more SF} \quad 2

\text{Penalise incorrect units} \quad 2

17. (a)  

(i)  
Weighted average (mass) of 1 atom (1)  
on a scale in which 1 atom of $^{12}$C = 12 units / compared to  
1/12 atom of $^{12}$C (1) \quad 2

(ii)  
Number of protons plus / and neutrons or nucleons in a nucleus / an atom. \quad 1

(iii)  
Atoms of same atomic number / same proton number (1)  
which differ in the number of neutrons (1) (in the nucleus) \quad 2

(b)  

(i)  
Concept of high energy electron collision:  
Electron bombardment / gun / acceleration / fired (1)  
knocks off electron / equation showing electron being knocked off (1) \quad 2

(ii)  
Positive, +, S$^+$ \quad 1

(iii)  
Voltage differential across plates / charged plates [plural] /  
electrostatic field / electric field \quad 1

(c)  
\[ [95.0 \times 32 + 0.76 \times 33 + 4.24 \times 34] / 100 \] \text{ (1)}
\[ = 32.0924 \approx 32.09 \text{ NOT 32 or 32.10} \quad 2 \]

(d)  
\[ 1s^22s^22p^63s^23p^4 \] \quad 1
18. (a) **Trend** - boiling point increases down the group / from He to Xe or Rn (1)
**Reason** – number of electrons (and protons) increases (1)
Increased strength of van der Waals’ / dispersion / London forces / temporary
dipoles / induced dipoles / attraction between nucleus and electrons on other atom (1)

(b) (i) P or S or Cl / P₄, S₂, S₈, Cl₁₂ / names
(ii) • The atoms of silicon are held together by covalent bonds across the whole structure (1)
• High energy required to break bonds (1) consequential on indication of covalent. Mention of ionic or metallic or van der Waals’ forces loses both marks. (2)
(iii) • 1. Magnesium ion has larger charge (density) than sodium / magnesium contributes two electrons per atom to the ‘sea’ of electrons. (1)
• 2. Hence magnesium (ions) have greater attraction for (sea of) electrons than sodium. (1)
• 3. Melting requires energy to overcome this attraction, hence greater attraction means higher melting temperature (1)
This mark is consequential upon the concept of metallic bonding. (3)

19. (a) 31e, 38n, 31p
All correct → (2)
2 correct → (1) 2

(b) \[ \frac{(69 \times 60) + (71 \times 40)}{100} \]
\[ = \frac{(4140 + 2840)}{100} \]
\[ = 69.8 \] (1)

-1 for more or less than 3 SF 2

(c) Metallic/ metal 1

[5]

20. (a) (i) \( (1s^2)2s^22p^6 \)
\[ OR \ 2s^22p_22p_y2p_z^2 \] 1

(ii) \( 2s^22p^63s^23p^63d^{10}4s^24p^6 \) / \( 2s^22p^63s^23p^64s^23d^{10}4p^6 \) 1

(b) Krypton because greater/ stronger *(NOT more)* van der Waals’/ London/ dispersion/ temporary or induced dipole forces / attractions (1)
Because of larger number of **electrons**/ extra shell(s) of electrons (1) 2

(c) (i) Sample bombarded/ fired at by electrons/ electron gun (1)
Knocks out/ loses/ removes electrons from the sample
Or equation (1) 2

(ii) Electric/electrostatic field/ (negatively) charged plates/ potential difference 1

(iii) Magnetic field/ (electro)magnet 1

[8]

21. (a) Weighted/ reference to abundance **average mass of atoms/ isotopes**
(in sample) (1)
Relative to (mass of one atom of) $^{12}$C (1) 2

(b) $^{19}$ F
F and atomic no.9(1)
mass no.19 (1) 2

(c) Any (named) group 3 element (1) –
Big jump between 3$^{rd}$ and 4$^{th}$ I.E./ $1^{st}$ three electrons removed easily./
4$^{th}$ electron in lower energy level/ gained stable octet after 3$e^-$ removed (1) 2

[6]

22. Si: giant molecular/ atomic/ structure
**OR** macro molecular/ atomic/ structure
**OR** Lattice
**OR** network
**OR** diagram with a minimum of 5 atoms shown with continuation (1)

P: **molecular OR** exists as P$_4$ (1)

Si: covalent bonds to break (1)
P: intermolecular forces/ van der Waals’ forces between molecules to overcome (1)

Therefore more energy to separate silicon atoms (1) – *dependent on a reasonable explanation for Si and P* 5

[5]
23. (a) Diagram showing
Electrons 2, 8 (1)
Charge 2+ (1) 2

(b) Energy/light/radiation
is emitted outside the visible spectrum/ in UV region
or frequency/wavelength/emission outside visible region. 1

24. (a) (i) Same numbers of protons/electrons (1)
Different numbers of neutrons (1) 2
(ii) \( X \times 69/100 + (100 - X) \times 71/100 \)
\( = 69.8 \) Method (1)
\( . \ X = 60\% \) Answer (1) 2

(b) (i) \( \text{Ga(g)} - e^- \rightarrow \text{Ga}^+(g) \)
Entities (1)
states (1) 2
(ii) As the ion becomes more positive it is harder to remove (negative) electrons / same nuclear charge attracting fewer electrons 1
(iii) An electron is removed from a lower/different quantum shell (1)
which is closer to the nucleus (1)
\emph{NOT} shielding arguments 2

(c) (i) \( \text{GaCl}_3 / \text{Ga}_2\text{Cl}_6 \) 1
(ii) Conductivity measurement / electrodes and simple circuit /
electrolyse solution (1)
(High) reading for electrical conductivity / bulb lights/ high meter
reading/ \( \text{Cl}_2 \) formed (1)
Microscope slide, filter paper etc / U-tube method –
provided detailed \textbf{1 max}
ALLOW \( \text{AgNO}_3(aq) \) (1) white ppt (1) 2

[12]

25. (a) (i) Idea of \textbf{impact} with \textbf{energy}
fast electrons strike sample/ high energy/accelerated electrons /electrons
fired at sample/ sample bombarded with /blasted with electrons from
electron gun (1)
Removes an electron/ knock out electrons/ eqn \( X \rightarrow X^+ + e^- \) (1) 2
(ii) magnetic field /magnet / electromagnet \emph{NOT} charged plates
ALLOW magnetic plates 1
(b) \[(60.4 \times 69) + (39.6 \times 71) / 60.4 + 39.6\] (1)
= 69.8 (1)
69.792 scores 1 (out of 2) 2

(c) (i) B (1)
  mass no. 10 (1)
  \[^{10}\text{B} / \text{B}^{10}\] (2)
  If + is added max (1) ie for mass number 2
(ii) 
..2s^22p^1
(iii) BCl₃
  If an equation for formation of BCl₃ is given, look for BCl₃ and ignore rest 1 [9]

26. (a) (i) ALLOW 3 or 4 sig figs – penalise once only
  MUST be some working
  moles P = 93/31 = 3.0 (1)
  moles PCl₃ also = 3.0 (1)
  mass PCl₃ = 137.5 × 3.0 = 412.5 / 413 (g) (1)
  OR alternative route
  Max 2 if wrong units 3

(ii) moles Cl₂ = 3/2 × 3 = 4.5 (1)
  volume of Cl₂ = 4.5 × 24 = 108 (dm³) (1) - consequential on 1st mark 2

(iii) Cl₂ with attempt at reason (1)
  because gains electrons / ox. no. becomes more negative / oxidation number decreases / 0 \rightarrow -1
  OR
  P loses electrons / oxidation number increases / 0 \rightarrow +3 (1) 2

(b) (i) Outer shell of P in a molecule (1)
  Cl lone pairs / six more electrons around each Cl (1)
  Lone pair must be in the same space. 2

(ii) Trigonal pyramidal diag. (1)
  Must be some attempt to show 3-D. A poor diagram can be rescued by a correct name.
  100 – 108° (1) NOT consequential 2

(c) Tetrahedral 1 [12]
27. (a) bonding: (giant) **covalent** (1)
    Diag. shows at least 5 carbon atoms correctly joined (1)
    plus a hexagonal ring (1)
    Must NOT be graphite

   (b) **ions** mobile (in molten) / can move (1) **NOT “free” on its own**
    fixed positions in solid / cannot move (1)
    **Max 1** if only one ion mentioned eg Na\(^+\)  

28. (a) (i) energy/enthalpy/heat energy change per mole (1) **Change ≡ required**
    for removal of one electron / to form singly positive charged ion (1)
    from **gas atoms** (1)
    Could get 2 marks for \(X(g) \rightarrow X^+(g) + e^-\)  

   (ii) increases **plus some attempt at an explanation** (1)
    nucleus more positive / more protons/increased charge (1)
    **outer** electrons in same shell / same shielding/electrons being lost
    from the same shell
    OR atoms smaller so greater attraction/need more energy to be removed (1)
    “Decreases” 0 (out of 3)  

   (b) (i) \(N(g) + e^- \rightarrow N^{2-}(g)\)
    species (1)
    both state symbols (1)  

   (ii) (energy needed to overcome) repulsion (1) – **must relate to negatively**
    **charged species.**
    between electron and negative ion (1)
    **ACCEPT “negative particles” if eqn in (i) correct**
    If “repulsion between electrons coming in and those already there”
    **ALLOW 1st mark**  

29. 160  

30. \(1s^22s^22p^63s^2\)  

   [5]

   [10]

   [1]
31. (a) (i) \[ \text{C}_2\text{H}_6\text{(g)}(I) \rightarrow \text{C}_2\text{H}_4\text{(g)} + \text{H}_2\text{(g)} \]
   *If a state symbol is missing (0)*
   
   (ii) At high pressure reaction goes in direction to reduce pressure/to oppose change by Le Chatelier's principle (1)
   towards side with fewer molecules/moles (1)

(b) Shapes of orbitals between and above carbon

\[ \pi \quad \text{C} \quad \text{C} \quad \sigma \]

*If p orbitals drawn must show overlapping*

Shapes (1) ACCEPT crescents for \( \pi \) bonds NOT lines for \( \sigma \) bond
Labels (1)

(c) Addition of bromine *water/solution (1)*
   from yellow/brown/orange to *colourless (1)*
   OR
   *acidified* potassium manganate(VII) (1)
   from pink/purple to *colourless (1)*

(d) Addition (1)
   Electrophilic/electrophile OR appropriate *explanation (1)*

32. (a) (i) \[ \begin{array}{c}
\text{H} \quad \text{H} \\
\text{O} \quad \text{O}
\end{array} \]

*ACCEPT all dots/crosses*

(ii) \[ \begin{array}{c}
\text{H} \quad \text{H} \\
\text{P} \quad \text{H}
\end{array} \]

Trigonal pyramid/Tetrahedral/‘Three leg stool’ shape (1) –
*must be some attempt at 3D or correct name*

107° *ALLOW 92-108 (1)*
(iii) repulsion between four pairs of electrons gives tetrahedral shape (1)
Greater repulsion of non-bonding electrons/lone pair closes down tetrahedral bond angle (1) 2

(b) (i) \( \text{PH}_3(g) \rightarrow \text{P}(g) + 3\text{H}(g) \) 1
(ii) Hess applied (1)
Multiples (1)
Correct answer + 963(0.2)/960 kJ mol\(^{-1}\) (1) 3
(iii) Answer to (ii) divided by 3
+ 321(0.1)/320 kJ mol\(^{-1}\) 1

33. (a) (i) The mass of an atom (of the isotope) (1) – NOT average mass…
relative to 1/12\(^{th}\) the mass of a \(^{12}\text{C}\) atom
\( OR \)
relative to \(^{12}\text{C} = 12\) (1) – stand alone mark
\( An\ answer\ all\ in\ moles\ can\ get\ 2\ marks\ 
Atom need only be mentioned once. \( If\ not\ mentioned 1\ (out\ of 2)\) 2

(ii) Both have 35 protons (1)
\(^{79}\text{Br}\) has 44 neutrons (1)
\(^{81}\text{Br}\) has 46 neutrons (1) 3

(b) \( {^{79}\text{Br}}^{-}\text{Br}^{+} \) (1)
\( {^{79}\text{Br}}^{-}\text{Br}^{+} \) (1)
\( {^{81}\text{Br}}^{-}\text{Br}^{+} \) (1)
\( -1 \ for\ no\ charge\ then\ check\ the\ rest\ 
If\ give\ \(^{79}\text{Br} + \text{Br}^{+}\) etc with or without charge 1 (out of 3)
\( 79 + 79\ldots all\ three\ must\ be\ given\ 1\ (out\ of 3)\) 3

34. (a) Al atom is \((1s^2)\ 2s^2\ 2p^6\ 3s^2\ 3p^1\) (1)
Al\(^{3+}\) ion is \((1s^2)\ 2s^2\ 2p^6\) (1) 2
(b) The structure is a regular array/lattice of positive ions (1) NOT nuclei surrounded by delocalised/‘a sea of’ electrons (1)

1st two marks can be on a diagram

(It conducts electricity) because the electrons are mobile. (1) 3

(c) (i) Energy/enthalpy change per mole (1)

For \( E(g) \rightarrow E'(g) + e^{(g)} \) (2)

OR equivalent in words 3

(ii) In aluminium the outer electron is in the (3)p orbital whereas in magnesium it is in the (3)s orbital (1) – comparison between p and s required

so aluminium’s outer electron is in a higher energy (level)

OR

the (3)p electron is more shielded (and so less energy is needed to remove it.) (1) 2

[10]

35. (a) (i) \( \text{H} \quad \text{OR all dots/crosses} \)

shared pair (1)

correct outer shell (1) – consequential on 1st mark 2

(ii) Because HI has more electrons (1) NOT iodine/iodide

NOT because atoms are bigger/heavier

it has stronger/larger induced dipole / vdW / London / dispersion forces (1)

more energy is required to separate the molecules/break/overcome vdW forces (1) 3
(b) (i) \[ \text{HI} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \Gamma \]

*IGNORE state symbols*

*NOT HI \rightarrow \text{H}^+ (aq) + \Gamma (aq)*

(ii) It forms (hydrated) hydrogen/hydroxonium ions

*Any reference to H$^+$ will suffice*

*NOT proton donor*

(c) (i) \[ \text{CaO(s) + 2HCl(aq) \rightarrow CaCl}_2(aq) + \text{H}_2\text{O(l)} \]

*equation (1)*

*state symbols consequential on correct equation (1)*

(ii) Because the surface of the calcium oxide gets coated with *insoluble/sparingly soluble / impermeable calcium sulphate*

*“A protective layer of …. ≡ impermeable and coated*

36. (a) \(\sigma\) bond:

diagram showing the head on overlap between two (s or p or s & p) orbitals (1),

\[\text{Diagram 1}\]

\[\text{Diagram 2}\]

\[\text{Diagram 3}\]

\[\text{Diagram 4}\]

\(\pi\) bond:

diagram showing the side by side overlap of two (p) orbitals (1)

\[\text{Diagram 5}\]

\[\text{Diagram 6}\]

\[\text{Diagram 7}\]

\[\text{Diagram 8}\]

*but not alone*
(b)  
(i) Methane is tetrahedral (1) – stated or drawn 3D  
It has 4 pairs of electrons (1)  
Which repel to a position of maximum separation / minimum repulsion  
could be awarded from (ii) (1) – can score even if first two are wrong  
**Do not allow atoms or bonds repelling**  

(ii) Shape of CO₂ is linear (1) – can be a diagram  
1st mark is stand alone  
because there are 2 pairs of σ electrons / 2 sets of bonding electrons / 2  
areas of negative charge/2 double bonds (1)  

37. Too many electrons  
No electrons between the positive ions  
Positive ions touching / should have gaps  

Check words like ion / molecule / atom / electron / are correctly used to award full marks  

38.  
(a) Mg + ½ O₂ → MgO  
**IGNORE state symbols**  
**ALLOW multiples**  

(b) Correct number of electrons on both ions (must include inner shell) (1)  
Drawn or “2,8”  
Correct charges on each ion (1)  
Free standing marks  
**ACCEPT all dots/ crosses or combination**  
Max 1 if elements not identified  

(c) (Electrostatic) attraction between positive ions and electrons (1)  
Symbol with correct charge can be specified  
**NOT** nuclei/ protons for positive ions  
**NOT** held together for attraction  
Electrons delocalised / sea of electrons free moving (1)  
are mobile / can move / flow (under a potential difference) (1)  
**NOT** “free” on its own  
**NOT** carry the charge (1)  

[7]  

[2]  

[6]
39. (a) (i) \( (1s^2)2s^22p^63s^23p^64s^2 \)
OR
\( (1s^2)2s^22p^63s^23p^63d^24s^2 \)
OR
\( (1s^2)2s^22p^63s^23p^64s^23d^0 \)
ALLOW subscript numbers in place of superscripts

\( 2p^6 \equiv 2p_x^22p_y^22p_z^2 \) numbers must be superscript

\( 3p^6 \equiv 3p_x^23p_y^23p_z^2 \) numbers must be superscript

IGNORE caps

(b) (i) Energy/enthalpy / heat energy change / required per mole (1)

NOT evolved

for the removal of 1 electron (1)

from gaseous atoms NOT molecules (1)

OR

\( X(g) \rightarrow X^+(g) + e^- \) states required for 2\(^{nd}\) and 3\(^{rd}\) marks (2)

Can be actual symbol of an element

ACCEPT - e\(^{(\text{c})}\) (3)

(ii) (Even though) there is a greater nuclear charge / number of protons

OR nuclear charge increases down the group (1)

outer / valency electron(s) further from nucleus NOT “shell” on its own (1)

and more shielded OR more (filled) inner shells/electrons (1)

(c) (i) Similarity: number of protons (proton number) (1)

IGNORE electrons

NOT atomic number

Difference: number of neutrons

[correct numbers can be given]

NOT atomic mass or number of nucleons (1)

\[ \frac{(24 \times 78.6) + (25 \times 10.1) + (26 \times 11.3)}{100} = 24.3 \]

Method (1)

Answer must be to 3 SF (1)

Correct answer to 3 SF with some working (2)

IGNORE g or g mol\(^{-1}\) other wrong units lose a mark (2)
40. (a) (i) moles silicon = \( \frac{10}{28} = 0.357 \) (1)
    moles SiCl\(_4\) = 0.357 (1)
    mass = \( 0.357 \times 170 = 60.7\) g / 60.69 g (g) ALLOW 2 - 4 SF (1)
    OR by mass ratio
    Units not required but if given must be correct.
    Correct answer with some recognisable working (3)
    Correct answer with no working (1) 3

(ii) moles chlorine = \( 2 \times 0.357 \)  moles Si \( \times 2 \) (1) (1)
    :. vol = \( 0.714 \times 24.0 = 17.1 \) (dm\(^3\)) moles Cl\(_2\) \( \times 24 \) (1) (1)
    ALLOW TE from (i)
    ALLOW 2 - 4 SF
    Units not required, but if given must be correct
    Correct answer with some recognisable working (2)
    Correct answer with no working (1)
    Penalise SF once only across (i) and (ii) 2
    Penalise units once across (i) and (ii)

<table>
<thead>
<tr>
<th>ratio</th>
<th>10/28</th>
<th>10/28</th>
<th>10/28</th>
<th>10/28</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.357</td>
<td>0.36</td>
<td>0.357</td>
<td>0.357</td>
</tr>
<tr>
<td>loses SF mark</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mass</td>
<td>60.69</td>
<td>60.71</td>
<td>61.2</td>
<td>68</td>
</tr>
<tr>
<td>vol</td>
<td>17.14</td>
<td>17.14</td>
<td>17.3</td>
<td>19.2</td>
</tr>
</tbody>
</table>
Wedges not required e.g.
Atoms can be represented by circles etc provided there are 4 of one type and
1 of another
tetrahedral (I)
Any angle in range 109 – 109.5° (I)
degree symbol can be shown on diagram (I)
4 (bond) pairs of electrons / 4 bonding pairs (I)
NOT bonds
NOT atoms
NOT groups of electrons
Repel to position of minimum repulsion / potential energy NOT “Equal repulsion” (I)
OR Repel to position of maximum separation
  4th mark cannot be awarded if atoms referred to

(i) Si and Cl have different electronegativities / Cl attracts the bonding
electrons very / more strongly / Si less electronegative than Cl / Cl
very electronegative
(ii) symmetrical molecule / chlorines equally spaced (I)
bond polarities / dipoles / vectors cancel
OR
Centres of positive and negative charge coincide / vectors cancel. (I)  

41. (a) (i) \( \text{Mg}^+(g) \rightarrow \text{Mg}^{2+}(g) + e^-(g)) / \text{Mg}^+(g) - e^-(g)) \rightarrow \text{Mg}^{2+}(g) \)
Equation (I)
State symbols (I)
2nd mark dependent on 1st except
- e on wrong side OR
- 1st or 3rd ionisation energy equation quoted OR
- cumulative 1st and 2nd ionisation energy quoted  
(ii) B / b – can be shown on graph

(b) 
\[
\begin{pmatrix}
& & \text{F}^+ \\
& & \\
\text{Mg}^+ & & \\
& & \\
& & \\
\end{pmatrix}
\begin{pmatrix}
& & \text{F}^- \\
& & \\
\text{Mg}^+ & & \\
& & \\
\text{F}^+ & & \\
\end{pmatrix}
\begin{pmatrix}
& & \text{F}^- \\
& & \\
\text{Mg}^+ & & \\
& & \\
& & \\
\end{pmatrix}
\]
Dots and crosses (1) — all dots/crosses acceptable
Ensure that all electrons are being shown
Charges (1) — 2nd mark independent of 1st
2nd $F^-$ ion and square brackets not essential
ALLOW “Fl” for “F”
If one of the ions is completely correct (electrons & charge) 1 (out of 2) 2

42. (a) (i) Protons = 19 and electrons = 19 (1)
neutrons = 20 (1)
ACCEPT as words or numbers 2

(ii) $1s^22s^22p^63s^23p^6(3d^0)4s^1$
ALLOW subscripts
MUST be in this order 1

(b) (i) MnO$_4$$^{(1)-}$ 1

(ii) Purple/violet/mauve/lilac/pink colour has moved towards/is at the positive/left-hand electrode/anode
If purple colour associated with K$^+$ (0) 1

(iii) Blue colour moves towards the negative/right-hand electrode/cathode (1)
The Cu$^{2+}$/positive copper ion (is blue) (and is attracted to it) (1)
ALLOW:
Red/brown deposit forms on cathode (1)
Cu$^{2+}$ + 2e$^-$ Cu or in words (1)
OR
Effervescence at anode (1)
4OH$^-$ - 4e$^-$ 2H$_2$O + O$_2$, or in words (1) 2
43. (a) (i) moles Na = \( \frac{92}{23} = 4 \) = moles NaCl
mass NaCl = \( 4 \times 58.5 = 234 \) (g)

Penalise use of atomic numbers once
Incorrect answer scores (1) only if moles (NaCl) mentioned

OR
23g Na \( \Rightarrow \) 58.5g NaCl (1)
Mass NaCl = \( \frac{92 \times 58.5}{23} = 234 \) (g) (1)

(ii) \( \frac{4}{10} = 0.40 \text{ mol dm}^{-3} \) OR \( \frac{234}{10} = 23.4 \text{ g dm}^{-3} \)
consequential on (a)(i)
units required (1)

(iii) moles chlorine = 2
vol = \( 2 \times 24 = 48 \) (dm\(^3\))
Consequential on (a)(i)

Correct answer (some working) (2)
Correct answer (no working) (1)
Incorrect answer scores (1) only if moles of Cl\(_2\) mentioned (2)

(b) Regular pattern or lattice of (sodium) ions
in a sea of electrons / delocalised electrons
ALLOW “cloud of electrons”
electrons are mobile / free to move (under an applied potential and so conduct electricity)
NOT ‘free’ on its own or carry the charge (3)

(c) (i) Energy (allow enthalpy) required per mole
to remove 1 electron (per atom)
from gaseous atoms
OR
\( X(g) \rightarrow X^+(g) + e^- \)
Species (1)
State symbols (1) – only on correct equation
Electron affinity defined (0) (3)
(ii) chlorine has more protons / nucleus more positive
    Same shielding / same number of inner electrons/atomic
    radius less  ALLOW outer electron(s) in same shell
    (so more energy required)
    OR
    effective nuclear charge increases  (I)  2

44. (a) Number of moles / \( \frac{3.5}{7} = 0.50 \) / \( \text{mol} \)  (I)
    If candidate does first part only, working must be shown
    Number of atoms = \( 3.01 \times 10^{23} \)  (I)
    ACCEPT 3.0  OR  3 OR 3.010\((\times 10^{23}) \)
    NOT 3.01\(^{23} \)
    If all working shown, allow TE for 2\(^{nd} \) mark  Ignore units
    Correct answer with no working (2)  2

(b) (i) \( 2\text{Li}(s) + 2\text{H}^+(aq) \rightarrow 2\text{Li}^+(aq) + \text{H}_2(g) \)
    ALLOW multiples  Ignore state symbols  1

(ii) 

\[
\begin{array}{c}
\text{Li}^+ \\
\text{Cl}^-
\end{array}
\]

(1)  Allow all dots or all crosses on Cl
    Max 1 if no/wrong charges
    If covalent (0)
    Do NOT penalise if electrons not shown in pairs
    Maximum 1 if Li and Cl not labelled
    Li and Cl symbols can go below diagram
    Square brackets not essential
    Allow number of protons/positive charges in nucleus as
    alternative to symbols for Li and Cl  2
(iii) Any two from:

Temp 298 K / 25 °C OR “at a specified temperature”

Unit of temperature needed

NOT “room temperature”

(1) Concentration 1 mol dm\(^{-3}\) / 1 molar

Pressure 1 atm / 10\(^5\) Pa / 1.01 \times 10\(^5\) Pa / 10\(^2\) k Pa /

101 k Pa/10\(^5\) N m\(^{-2}\) / 76 cm Hg

NOT “pressure of hydrogen” OR “pressure of reactants”

NOT atmospheric pressure

Must be the most stable/usual/normal physical states

NOT “standard states”

If more than 2 conditions given, deduct 1 mark for each incorrect answer 2

45. (a)

<table>
<thead>
<tr>
<th>Protons</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrons</td>
<td>18</td>
</tr>
<tr>
<td>Neutrons</td>
<td>22</td>
</tr>
</tbody>
</table>

(1)

(b) Position depends on proton number/ atomic number (not mass) / Ar atom has 1 less proton than K atom.

IGNORE references to number of protons = number of electrons 1

(c) Average = \(\frac{36 \times 1.34 + 38 \times 0.16 + 40 \times 98.5}{100}\)

= 39.9 \(\text{(1)}\)

–1 for more or less than 3 SF

IGNORE units 2

(d) 1s\(^2\) 2s\(^2\) 2p\(^6\) 3s\(^2\) 3p\(^6\)

Numbers following letters can be subscript or superscript

s and p can be upper or lower case 1

(e) (i) \(\text{Ar(g)} \rightarrow \text{Ar}^+ (g) + e^{-} ((g))\)

OR \(\text{Ar(g)} - e^{-} ((g)) \rightarrow \text{Ar}^+ (g)\)

Symbol of Ar must be correct 1

(ii) Potassium value well below sulphur in range 250-750 \(\text{(1)}\)

Low ionisation energy as electron which is removed is more shielded / further from the nucleus / in a higher energy level \(\text{(1)}\)

NOT just ‘because electron is in fourth shell’ 2
(iii) Sulphur has 4 electrons in (3) p / phosphorus has 3 \textbf{(1)}

\textit{Plus any one from:}

Electrons in shared p orbitals repel (so are lost more easily) \textbf{(1)}

half-filled sub-shells are (more) stable \textbf{(1)}

phosphorus has half-filled sub-shell \textbf{(1)}

(iv) Chlorine has more protons/greater nuclear charge \textbf{(1)}

Shielding unchanged / electrons in same shell/ electrons same
distance from nucleus \textbf{(1)}

\textit{Could be answered in terms of S having fewer protons} \textbf{2}

(f) Argon inert / unreactive so filament can’t react/ vaporises less easily/
lasts longer \textbf{(1)} \textbf{1} \textbf{[14]}

46. (a) \textbf{.2s^22p^2} \textit{OR} \textbf{1s^22s^22p^2} \textit{OR} \textbf{(1s^2)2s^22p_x^12p_y^1}

\textit{ALLOW capitals and subscripts} \textbf{1}

(b) large gap/jump between \textbf{4th} and \textbf{5th} ionisation energies (so fifth in inner shell) \textbf{1}

(c) 4 pairs of electrons around C atom \textbf{(1)}

all lone pairs shown \textbf{(1)}

\textit{Mark independently} \textbf{2}

\textbf{PLEASE MARK INDEPENDENTLY}

\begin{align*}
\text{Cl}_x & \text{ Cl}_x \\
\text{Cl} & \text{ Cl} \\
\text{O} & \text{ Cl} \\
\text{x} & \text{x} \quad \text{x} & \text{x} \\
\text{x} & \text{O} \quad \text{x} & \text{x} \\
\text{x} & \text{x} \quad \text{x} & \text{x} \\
\end{align*}

\textit{ALLOW all dots/crosses} \textbf{2}

\textit{Any attempt at an ionic diagram} \textbf{(0)}

(d) (i) High energy/fast/gun electrons hit/strike

\textit{OR} bombarded by electrons \textbf{(1)}

Removes/knocks out electron \textbf{(1)} \textbf{2}

\textit{OR} equation \textbf{eg} \textbf{X \rightarrow X^+ + e^{(-)}} \textit{IGNORE state symbols}

\textit{If knock out is mentioned, hit/strike is not required in 1st mark}

(ii) magnetic field/magnet/electromagnet/magnetic plates \textbf{1}
(e) (i) mass of one **atom** (of the isotope) (1)  
relative to 1/12\(^{th}\) of the mass of (1)  
a carbon -12 **atom** (1)  

*OR 2\(^{nd}\) and 3\(^{rd}\) marks can be awarded as follows:*

On a scale where a \(^{12}\)C atom (1)  
has a mass of 12 (NOT grams) (1)  

*Word “atom” need only be mentioned once*

*Word “mass” need only be mentioned once*

If define R.A.M......**max1**

(ii) 162 **IGNORE** units 1

(iii) (atoms with) same no. of protons (1)  
NOT same atomic number  

*“different number of electrons” loses 1\(^{st}\) mark but **IGNORE**  
“same number of electrons”*

different number of neutrons (1)  
NOT different mass number  

*Penalise incorrect reference to number of electrons*

(iv) same number of electrons **IGNORE** “same number of protons”  
OR same electronic configuration/pattern/structure  
NOT same number in outer orbit 1

47. (a) (i) Covalent 1

(ii) Induced-dipole(-induced dipole)/dispersion/London/v der Waals/vdw  
**Temporary or instantaneous can be used instead of induced**  

NOT “dipole” forces  
NOT permanent dipole  
NOT dipole-dipole 1

(iii) polymer has stronger/more vdw/intermolecular forces (1)  
ALLOW dipole forces  
because it has more electrons/larger electron cloud/more contact area (1)  
NOT larger molecules/surface area  

so more energy/heat needed to overcome/break these forces  
*OR* so more energy/heat needed to separate these molecules (1)  
NOT breaking **bonds**  
3\(^{rd}\) mark is NOT stand alone 3

(b) **strong** attraction between Mg **ions**/Mg\(^{2+}\)/cations/metal ions (1)  
NOT electrostatic forces/metallic bonds
48. (a) (i) \(-1/-1, 0 \quad -1/-1, 0\)

*minus can be either side, sub or superscript*

iodine no’s correct (1)
chlorine no’s correct (1)

(ii) chlorine oxidation number goes down/goes from 0 to -1, so reduced (1)

iodine oxidation number goes up/goes from -1 to 0, so oxidised (1)

Mark consequentially on (a)(i)

(iii) moles NaI = \(\frac{30.0}{150} = 0.2\) (1)

moles I\(_2\) = 0.1 (1)

mass of I\(_2\) = 0.1 \times 254 = 25.4 (g) (1)

OR

300g NaI (1) \(\rightarrow\) 254g I\(_2\) (1)

\(30.0 \times \frac{254}{300} = 25.4(\text{g})\) (1)

Correct answer with some working (3)
Use of atomic numbers 2 max
Penalise wrong units 3

(iv) vol = 0.1 \times 24 = 2.4 (dm\(^3\))

If not 2.4, check for consequential on (a)(iii)

(b) (i) black/grey/grey-black (1)

*NOT* blue-black
*NOT* purple
*IGNORE* shiny/silvery
Solid (1)
(ii) $I(g) \rightarrow I^-(g) + e^-$ \textit{OR} \hspace{1cm} I(g) - e^- \rightarrow I^-(g)$

species (1)

State symbols (1) - award state symbols mark only if species correct and in correct place, or if wrong halogen used

If $I_2$ OR $\frac{1}{2}I_2$ (0) \hspace{1cm} 2

49. (a) (i) 4 pairs of electrons /2 lone pairs and 2 bond pairs (1)

so electron pairs arranged tetrahedrally

\textit{OR}

Arranged to give maximum separation/minimum repulsion (1) \hspace{1cm} 2

(ii) $103 - 105 \text{ (1)}$

lone pair repulsion $> \text{ bond pair repulsion (1)}$ \hspace{1cm} 2

(b) (i) trigonal planar diagram (1)

e.g \hspace{1cm} \text{two opposite wedges gets (1)}

\hspace{1cm} \text{three wedges of two types gets (1)}

\hspace{1cm} \text{one wedge only gets (0)}

\text{IGNORE name}

$120 \text{ (1)}$ marked on diagram (1) - \textit{stand alone} \hspace{1cm} 2

(ii) B and Cl have different electronegativities / Cl more electronegative than B

\textit{OR} different electronegativities explained \hspace{1cm} 1

(iii) Dipoles (or vectors) cancel/symmetrical molecule/centres of positive and negative charges coincide

\textit{IGNORE} polarity cancels \hspace{1cm} 1

(iv) Induced-dipole(-induced dipole)/dispersion/London/v der Waals/vdw

\textit{Temporary or instantaneous can be used instead of induced}

\textit{NOT} “dipole” forces

\textit{NOT} permanent dipole

\textit{NOT} dipole-dipole \hspace{1cm} 1
(c) \[ \frac{14.9}{31} = (0.481) \quad \frac{85.1}{35.5} = (2.40) \quad (1) \]
\[ \frac{3.4}{0.481} = 7 \quad \text{so PCl}_5 \quad (1) \]

Use of atomic number max 1

50. (a) \[ L = \frac{79.0}{1.31 \times 10^{-22}} \quad (1) \]
\[ = 6.03 \times 10^{23} \quad (1) \]

–1 mark for SF error

Final answer must be \(6.03 \times 10^{23}\) for 2nd mark

Correct answer with no working (2)

6 \times 10^{23} / 6.02 \times 10^{23} quoted with no working (0)

Error in method, max (1)

(b) 80 is the average mass of Br atoms / isotopes

OR

There must be another/at least one Br isotope of mass greater than 80/with more than 45 neutrons

NOT naturally occurring isotope has mass 80

51. (a) (i) \( \text{H(g)} + \text{O(g)} + \text{Cl(g)} \quad \text{in top RH box} \)
\[ \frac{1}{2} \text{H}_2(g) + \frac{1}{2} \text{O}_2(g) + \frac{1}{2} \text{Cl}_2(g) \quad \text{in lower box} \]

Brackets around the state symbols are not required

(ii) \[ 589 - 667 = -78 \text{ (kJ mol}^{-1}) \]

ALLOW final answer on its own

(iii) \[ 667 - 464 = (+)203 \text{ (kJ mol}^{-1}) \]

ALLOW final answer on its own
(b) (i) \[ \text{H}^+ \text{O}^{++} \quad \text{ALLOW} \quad \text{H}^+ \text{Cl}^{++} \text{O}^{++} \]

ALLOW all dots/crosses
ALLOW 1 max if electrons are correct but atoms are not identified
If ionic dot and cross diagram (0)

(ii) 100 – 106° (I)

as lone / non-bonding pairs take up more space/
repel more strongly than bonded pairs (I)
NOT bonds being repelled/H and Cl being repelled

(c) No change (I)
as number of gaseous reactant molecules = number of gaseous product
molecules (I)
ALLOW 1 max if candidates state or imply a very small change with correct
justification
eg “hardly changes”
“doesn’t change much”
“very little effect/change”

52. (a) (i) 2(-)chloropropane

\[
\text{H} \quad \text{Cl} \quad \text{H} \\
\text{H} - \text{C} - \text{C} - \text{C} - \text{H} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{No internal TE from name to structure}
\]

MUST be fully displayed
(ii)

\[
\text{IGNORE rest of molecule }
\begin{align*}
\text{(1)} \\
\text{Mark independently} \\
\text{Must attack the carbon} \\
\text{ALLOW attack by oxygen or negative charge or lone pair}
\end{align*}
\]

\[
\text{ACCEPT OH NOT OH}
\]

\text{NOT } C^+

(b) (i) Elimination
\text{NOT in conjunction with additional incorrect information}
\text{eg "nucleophile"}

(ii) Sodium hydroxide / NaOH/potassium hydroxide / KOH (1)
\text{Any additional incorrect reagent (0)}
\text{NOT alkali on its own for 1st mark}
\text{Alcoholic solution / ethanolic solution and heat / warm / reflux (1)}
\text{2nd mark is dependent on mention of correct reagent or "alkali"}
\text{"aqueous" negates 2nd mark eg KOH(aq) + heat (1) – ie reagent mark}
\text{NaOH(alc) + heat (2)}

(c) (i) Hydrogen/H bonding

(ii)
\[
\begin{align*}
\text{H-bond and rest of molecule (1)} \\
\text{angle must be between 3 atoms for a correct H bond (1)} \\
\text{ALLOW HOH 106-108°}
\end{align*}
\]

1
(d) (i) 

\[
\begin{array}{c}
\text{H} & \text{CH}_3 & \text{H} & \text{CH}_3 \\
\text{H} & \text{C} & \text{C} & \text{C} \\
\text{H} & \text{H} & \text{H} & \text{H} \\
\end{array}
\]

IGNORE any “n” in this diagram

Brackets optional but continuation must be shown
4 carbon chain with 6Cs overall in structure (I)
methyl groups can be on C\(_1\) and C\(_3\), C\(_4\) and C\(_6\), C\(_2\) and C\(_4\), C\(_2\) and C\(_3\) (I)

\[
\begin{array}{c}
\text{H} & \text{CH}_3 \\
\text{C} & \text{C} \\
\text{H} & \text{H} \\
\end{array}
\]

1 max 2

(ii) (big molecule) so large number of electrons (I)
Hence large/strong van der Waals’ forces
(to be overcome to change state)(I) 2 [14]

53. (a) 

<table>
<thead>
<tr>
<th>Neutrons</th>
<th>Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 12Mg</td>
<td></td>
</tr>
<tr>
<td>26 12Mg</td>
<td>14</td>
</tr>
<tr>
<td>24 12Mg(^{2+})</td>
<td>10</td>
</tr>
</tbody>
</table>

1 mark each number 3

Accept words or numbers

(b) 

\[
\begin{array}{cccccc}
\text{Mg} & \text{1s} & \text{2s} & \text{2p} & \text{3s} & \text{3p} \\
\text{Cl} & \text{1s} & \text{2s} & \text{2p} & \text{3s} & \text{3p} \\
\end{array}
\]

Arrows can be
\[\uparrow\text{ for } \uparrow\]
\[\downarrow\text{ for } \downarrow\]

Accept both arrows up or both down 2

Reject numbers

(c) \(\text{Mg(s) + Cl}_2(\text{g}) \rightarrow \text{MgCl}_2(\text{s})\)
Formulae (1)
State symbols (1) – only if formulae correct or near miss for MgCl₂
(e.g. MgCl/Mg₂Cl)

Accept multiples
Accept Mg²⁺(Cl⁻)₂(s)

Reject “Mg²⁺ + 2Cl⁻” for MgCl₂
(0 mark)

\[
\frac{(56.25 \times 70) + (37.50 \times 72) + (6.25 \times 74)}{100}
\]
\[= 71 \text{ (1)}\]

Any unit max 1

2nd mark consequential on fraction provided 70, 72 and 74 used

Accept answer ≥ 2 SF

Reject use of Ar (0 mark)

Reject just “71” with no working (0 mark)

\[
\frac{4.73}{71} \text{ moles (1)}
\]

X 30.6 = 2.04 dm³ (1)

Answer with no working 1 max

Accept consequential if wrong answer to (d) used.

Accept 71 used when (d) incorrect

Accept answer ≥ 2 SF

Reject no or incorrect unit of volume (loses 1 mark)

(f) Type – Metallic(1)

Attraction between Mg²⁺ (1)

And (surrounding) sea of electrons/delocalised electrons (1)

Stand alone

Accept cations/positive ions /magnesium ions

Reject atoms/nuclei/ions

“force between” if used instead of “attraction”
(g) Ionic (1)

\[
\begin{align*}
\begin{bmatrix}
0 & 0 & \text{Mg} & 0 \\
0 & 0 & 0 & 0 \\
\end{bmatrix}^{2+} & \begin{bmatrix}
0 & 0 & \text{Cl} & 0 \\
0 & 0 & 0 & 0 \\
\end{bmatrix} \quad 2
\begin{bmatrix}
0 & 0 & \text{Cl} & 0 \\
0 & 0 & 0 & 0 \\
\end{bmatrix} \\
\end{align*}
\]

OR

\[
\begin{align*}
\begin{bmatrix}
0 & 0 & \text{Cl} & 0 \\
0 & 0 & 0 & 0 \\
\end{bmatrix} & \begin{bmatrix}
0 & 0 & \text{Mg} & 0 \\
0 & 0 & 0 & 0 \\
\end{bmatrix}^{2+} \begin{bmatrix}
0 & 0 & \text{Cl} & 0 \\
0 & 0 & 0 & 0 \\
\end{bmatrix} \\
\end{align*}
\]

Correct charges and number of ions (1)
Correct electronic structures (1)
Stand alone

Accept diagram without brackets

Accept Mg with no electrons shown
ie [Mg]^{2+}

Reject any suggestion of electrons being shared

Reject [Mg^+]^+

[17]

54. (a) Penalise lack of nucleus/atom once only in (i) and (ii)
Penalise use of element each time it occurs

(i) The number of protons in the nucleus of an atom (of an element)
   OR
   The number of protons in an atom/nucleus (of an element)

   Reject the number of protons in an element
   Reject the number of protons

(ii) The number of protons plus the number of neutrons in the nucleus (of an atom)
    OR
    number of nucleons (in the nucleus of an atom)

    Accept “and neutrons” instead of “plus the number of.......
    Reject the number of protons plus neutrons in an element
(b) (i) C and L (1)

(Group 0 elements) have the highest (first) ionisation energy
(of each period) (1)

Accept implied e.g. immediately precedes large drop

Reject high first I.E.

Stand alone

Accept group 0 elements have the highest peaks on the graph

Accept highest (effective) nuclear charge/highest number of
protons in period

Reject filled shell

Reject smallest atom

Reject same shielding

(ii) F (1)

Third after noble gas/C (1)

Or

first element in period with p electron (1) 2

Accept first mini dip after big drop

Accept lowest after Group 1/D in same period (1)

Accept (in F, e⁻ removed from) p orbital is at a higher energy
level than s orbital (in E)

Reject just “electron in p orbital”

Reject just “s orbitals shield p”

(iii) Increase in (effective) nuclear charge (1)

Same shielding

OR same number of electrons in inner shell/orbitals (1)

Stand alone

Accept number of protons/atomic number

Reject same distance from nucleus

Reject increased size of nucleus

Reject same number of shells

Reject electrons in same shell

[8]
55. (a) (i) Minimum of one shaded blob **and** one blob labelled (1)
Labels are:
Na\(^+\) or sodium ion **and** Cl\(^-\) or **chloride** ion

Reject Na and Cl
(i.e. no charge)
Reject sodium / **chlorine**

(ii) Strong (force of) **attraction** between (oppositely charged) ions (1)

Accept held together by strong ionic forces/bonds
Accept “attraction” may be implied by “breaking bonds”
a lot of energy needed to separate ions (1)

Accept a lot of energy implies “strong”
Accept break ionic bonds
Accept break lattice
Reject any reference to atoms
or molecules
Or covalent bonds
Or intermolecular forces
Or metallic bonds
**(scores zero)**
Reject all the bonds need to be broken

(b) Covalent between carbon atoms in plane (1)
Van der Waals’ between planes of carbon atoms (1)

Accept induced dipole/ dispersion/ London forces/temporary dipoles

Names not linked to bonds **(max 1)**

Reject giant covalent delocalised e−

(c) Covalent
Label not needed

Reject giant covalent **BUT do not penalise twice**

(d) Covalent bonds in diamond are shorter than the distance between layers in graphite (1)
The atoms in diamond are packed closer together (1)

Accept layers in graphite are far apart (1)
56. (a) SrF$_2$ (1)

Reject SrF$_2$

(b) fluoride ion showing all 10 electrons and a single negative charge

Accept all electrons can be the same

Can show rings
ALLOW F$^-$ for F

Reject

\[
\begin{array}{c}
\times \\
\times \\
\times \\
\circ \\
\circ \\
\times \\
\end{array}
\]

57. (a) Isotope(s)

(b) 40

(c) (i) mass spectrometer

Accept mass spectrometry

(ii) \[
(60.2 \times 69 + 39.8 \times 71) \div 100 = 69.796 = 69.8 \]

must be 3sf

Accept correct answer with no working (2)

Allow g or g mol$^{-1}$ or g/mol

Reject 1, 2, 4 or 5sf

Units of % (−1 mark)

(d) (i) (1s$^2$) 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ (1) 3d$^{10}$ 4s$^2$ 4p$^1$ (1)

Accept capitals/ subscripts/ any order
(ii) $Ga(g) \rightarrow Ga^+(g) + e^-(g)$
or $Ga(g) - e^-(g) \rightarrow Ga^-(g)$

Mark independently
formulae (I)
state symbols (I)

Accept $Ga^+(g) + e^-$

Reject (s) is wrong – take care to distinguish from (g)

(iii) B  

Accept 579, 1979, 2963, 6200

58. (a) $^{78}_{35}$Br: 44 neutrons (I)

$^{81}_{35}$Br: 35 protons (I)

$^{81}_{35}$Br: 36 electrons (I)  

(b) Na  $2s^2 2p^6 3s^1$ (I)

Br  $2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$ (I)

Ignore repeat of $1s^2$  

Allow subscripts and ignore capital letters

Allow $4s^2 3d^{10} 4p^5$

Allow $p$ as pxpypz with 2 in each

(c) They have the same (number of protons and) electron(ic) configuration
Same (number of protons and) electronic structure
Same (number of protons and) electron arrangement
same (number of protons and) number of electrons
MUST MENTION ELECTRONS  

Reject 'just' Same number of protons
Reject 'just' same number of electron shells
Reject same number of outer electrons
Reject same number of electrons in outer shell
Reject correct answer followed by reference to outer shell scores (0)
(d) Mass spectrometer

*Allow variations of spelling*

*Reject mass spec (1)*

\[
\frac{(78.93 \times 50.54) + (80.91 \times 49.46)}{100} \quad (1)
\]

\[= 79.91(1)\]

2nd mark consequential on transcription error data used
Correct answer with no working scores 2
Answer to 4 S.F. with NO units but allow g/mol

(f) Between the atoms: Covalent (1)

*Between the molecules*: Induced dipole-(induced) dipole
OR dispersion OR London OR van der Waals OR
instantaneous OR Temp dipole – (1) (forces) 2

*Accept variations on van der Waals such as de and walls, vdW*

*Reject dipole-dipole OR ‘JUST’ intermolecular forces*

*Reject ID-ID* 2

59. Ionic / electrovalent (1)

\[\text{[Na}^+ \text{]} \text{[: Br:]}^- \text{ OR [: Na:]}^+ \text{[: Br:]}^-\]

1 mark for correct charges
1 mark for electrons
Penalise wrong symbol only once
Allow dots or crosses
If choose to give inner shell electrons they must be correct

*Accept charge could be on central atom e.g. Na\(^+\)*

[ ] not necessary
If charges omitted can score electrons mark provided not
covalent i.e. sig gap between Na & Br
Arrow to show transfer of an electron on its own does not score
as this does not answer the question
Anything that looks covalent **scores zero.**
60. (a) (i) Enthalpy/heat/ energy required/change to remove 1 electron (1) from each of one mole (1) of gaseous atoms (of an element) (1)
Ignore references to gaseous electrons

Accept \( X(g) \rightarrow X^+(g) + e^- \)

2 marks for the change and the state but not the mol
Accept isolated atoms in place of gaseous

If incorrect equation given after correct def – 1 mark

(ii) \( O^+(g) \rightarrow O^{2+}(g) + e^- \)
Or
\( O^+(g) - e^- \rightarrow O^{2+}(g) \)
State symbols required 1

Reject \( E \) (for element) in place of \( O \)

(b) (i) There is a large increase after the removal of 6 electrons (1)

Accept large increase before removal of 7th electron

Accept (big) jump between 6 and 7

(Group) 6 (1) Stand alone

(Need to look at diagram for annotation) 2

(ii) Sulphur / S / \( S_8 \)
Not CQ 1

(c) \( S_8^+ \)
1 mark ‘\( S_8 \)’
1 mark ‘\( ^+ \)’ Stand alone 2

Accept \( ^{32}S_8^+ \)

[9]
61. 

\[
\begin{array}{c}
\text{Ca} \\
\text{O}
\end{array}
\]

Brackets not essential
Electrons correct for both ions (1)
Charges (allow 2+ or +2 and 2− or −2) (1)

Accept electrons can all be dots and/or crosses
Accept either ion completely correct
(i.e. electrons and charge) (1)

Charges can be shown outside structure, or inside against symbol

62. (a)

<table>
<thead>
<tr>
<th></th>
<th>Protons</th>
<th>Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>H(^-)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Li(^+)</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

1 mark per row (2)
Allow (1) for correct electrons column 2

(b) H\(^-\) is larger (0)
Same number of electrons for each ion ……. (1)
H\(^-\) has only 1 proton to hold them in place, whereas Li\(^+\) has 3 protons to pull them in more tightly (1)
“nuclear charge” can be used instead of “protons”

3 points to consider: −1 per error, or omission, from total of 2
H\(^-\) has a lower proton: electron ratio than Li\(^+\) (1 max)
H\(^-\) has fewer protons than electrons, whereas Li\(^+\) has more protons than electrons (1 max)
2 correct key points, but Li\(^+\) larger (1 max)

Allow TE from (a) if, and only if protons for Li\(^+\) > protons for H\(^-\) and number of electrons are the same for each ion 2

Accept H\(^-\) is smaller, based on 0 for the electrons in table (i.e. misread as H\(^+\)) plus justification (1 max)

63. (a) Group 1 / alkali metals (1)
(Relatively) large “jump” / gap / difference between Em\(_1\) and Em\(_2\) (1)
2nd mark dependent on 1st

Accept substantial drop for 1st ionisation energy from Q to R

(b) 6915–9000 (kJ mol⁻¹) (actual value: 7733 kJ mol⁻¹) (1)
500–730 (kJ mol⁻¹) (actual value: 578 kJ mol⁻¹) (1)  
2

(c) Q must be a noble gas /in group 8/0, since Q and R have consecutive atomic numbers (and R is in group 1) 
Accept Q as it has a very high / the highest first ionisation energy NOT “high ionisation energies” (generally)

(d) R²⁺(g) → R³⁺(g) + e⁻(g)
symbols and charges (1)
state symbols (1)
[Mark independently]  
Accept R²⁺(g) − e⁻ → R³⁺(g)

(e) Outermost electron(s) for an atom of X is /are in a shell further from the nucleus / shell of higher energy than that of R.
Accept answer based on “better shielding” from inner electrons

[8]

64. (a) (i) Copper
........3d¹⁰4s¹  
Accept subscripts/ignore capitals 4s inside 3d
Reject 3dº 4s²

(ii) Bromide ion
........3d¹⁰4s²4p⁶  
Accept subscript/ignore capitals 4s inside 3d
Reject 4p inside 3d
(b) The **average mass** (taking into account the abundance of each isotope) of the **atoms** (of that element) \( I \)
relative to \( 1/12 \)th the (mass of a)
carbon 12 atom
Or
relative to \( ^{12}\text{C} = 12 \) (exactly) \( I \)

*second mark stand alone*

\[ \text{Accept weighted/mean in place of average} \]

\[ \text{Atoms must be mentioned at least once to score } 2 \]

\[ \text{Accept average mass of a mole of atoms of an element relative} \]
\[ \text{to } 1/12^\text{th} \text{ mole of } ^{12}\text{C} / \text{relative to one mole of } ^{12}\text{C} = 12 \text{ (exactly)} \]

\[ \text{(2)} \]

(c) \[ \frac{[62.93 \times 69.17] + [64.93 \times 30.83]}{100} \]
\[ = 63.55 \text{ (1)} \]

must be to 2 decimal places
cq only on transcription error e.g.
69.71 provided answer to 2 d.p.

\[ \text{Accept 63.54 with some working scores (1)} \]

\[ \text{Correct answer alone scores (2)} \]

\[ \text{Answer should have no unit, but allow unit of } \text{“g mol}^{-1}\text{” but not} \]
\[ \text{“grams” or “g”} \]

(d) (i)  

<table>
<thead>
<tr>
<th></th>
<th>Cu</th>
<th>C</th>
<th>O</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>57.5</td>
<td>5.40</td>
<td>36.2</td>
<td>0.900</td>
</tr>
<tr>
<td></td>
<td>63.5</td>
<td>12</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0.906</td>
<td>0.450</td>
<td>2.26</td>
<td>0.900</td>
</tr>
<tr>
<td></td>
<td>2.01</td>
<td>1</td>
<td>5.02</td>
<td>2.00</td>
</tr>
</tbody>
</table>

*Use of atomic number scores 0*

Empirical formula \( \text{Cu}_2\text{CO}_3\text{H}_2 \)

\[ \text{Correct answer without working scores (2)} \]

\[ \text{(1) for dividing by atomic mass} \]

\[ \text{(1) stating empirical formula} \]

\[ \text{(2)} \]
(ii) Empirical formula mass \( = 221 = M_r \)
Molecular formula \( \text{Cu}_2\text{CO}_3\text{H}_2 \)

must show use of 221  

If use atomic number in (i) allow mark for \( \text{Cu}_2\text{CO}_3\text{H} \) and 220

allow any formula that adds up to the correct molecular formula

(e) (Highest \( = ^{65}\text{Cu} + 2\ ^{37}\text{Cl} \) = 139 )  
(Lowest \( = ^{63}\text{Cu} + 2\ ^{35}\text{Cl} \) = 133 )  
Ignore units  

65. (a) Energy/Enthalpy/heat change **per mole** for the (1)

accept “required” instead of “change”

removal of **one electron** (per atom) (1)

from 1 mole of **gaseous atoms** (1)

if wrong equation given with a correct definition **max 2**

\[ X(g) \rightarrow X^+(g) + e^- \] can score last 2 marks  

(b) Increase in shielding/screening (1)

increase in nuclear charge/more protons/atomic number (1)

increase in distance (of outermost electron)/larger atomic radius

or

(increase in) shielding outweighs nuclear charge (increase) (1)

accept electron at higher energy level

ignore references to: effective nuclear charge or nuclear attraction  

(c) (i) Na:Mg:Al
metallic (structure)

Si

giant atomic (structure)

P:S:Cl:Ar

simple molecular

**all three correct 1 mark**

(ii) **strong covalent bonds (1)**

(throughout the lattice and lots of energy) need to break **many** bonds (1)  

[11]
(iii) Aluminium supplies more electrons (per atom)/Al ion is more highly charged/Al ion is smaller/ Al ion has a higher charge density (1)

Accept reverse for Na

The (attractive) forces between the aluminium ions and the electrons are stronger/require more energy to break than in the case of sodium. (1)

Reject any reference to bonding other than metallic bond/ sea of electrons/ delocalised system

[11]

66. (i) Electrons have opposite spin

Reject a paired spin of the electrons
Reject to show they repel each other
Reject going in different directions
Reject due to reverse spin
Reject moving in opposite directions

(ii) Start from n = 3 energy level and going upwards at least to another energy level (1)
End at or just above n = ∞ energy level (1)

Reject arrow into writing

(iii) No because energy levels split into two (1)
(2)s and (2)p (with the 2p higher than the 2s) (1)

Accept no because there are 2s and 2p (1)
Accept sublevels (1) /Subshells

Reject no because increasingly hard to remove successive electrons

(iv) 1 electron in the n = 4 energy level and 8 electrons in the n = 3 energy level

Accept 2,8,8,1 for potassium
Accept n = 3 full, n = 4 1 electron
Reject one more level of electrons
Reject an extra full energy level
Reject more electrons in n=3

[6]
67. (a) (i) High energy/fast/gun electrons hit/strike
OR bombarded by electrons (1)

Removes/knocks out /causes loss of electron OR equation e.g.
X → X⁺ + e⁻ (1)
OR
X + e → X⁺ + 2e (1)

IGNORE state symbols
If knock out is mentioned, hit/strike is not required in 1st mark 2

Any suggestion that a negative ion is produced score zero overall

Reject if just “forms a cation/positive ion”, not sufficient for second mark

(ii) Mass (1)
Accept weight

Charge (1)
Accept Mass: charge ratio
OR m/e
OR m/z (1)

Ignore the following:
speed
kinetic energy
size/volume
radius
charge density
density 2
(b) **1st mark** (stand alone)
The mass of an **atom** (of the isotope) \((1)\)

**2nd mark** (stand alone)
Relative to \(1/12^{th}\) the mass of a \(^{12}\text{C}\) (atom)
OR
Relative to \(^{12}\text{C} = 12\) (exactly)
OR
On a scale where \(^{12}\text{C}\) has a mass of 12 \((1)\)

If ‘atom’ missing from 1st mark it can score if mentioned in 2nd mark 

*Accept*

1st mark
The mass of a mole of the **isotope** \((1)\)

2nd mark
Relative to \(1/12^{th}\) the mass of a **mole** of \(^{12}\text{C}\)
OR
On a scale where a **mole** of \(^{12}\text{C}\) has a mass of 12 g \((1)\)

**Must mention the word ‘mole’ at least once in these definitions**

*Answer must be either consistently atoms or moles in order to be awarded both*

Reject average mass/weighted average/
Reject element instead of isotope

\[
\begin{align*}
\text{[(}49.95 \times 4.345) + (51.94 \times 83.79) + (52.94 \times 9.501) + (53.94 \times 2.364)\text{]}/100 \quad (1) \\
= 51.9958 \\
= 52.00 \text{ must be to 4 SF} \quad (1)
\end{align*}
\]

Correct answer to 4SF with no working \((2)\)
Should not have units but allow g mol\(^{-1}\)
Allow error carried forward only on transcription error of mass or percentage

*Accept 51.99 scores } (1) \text{ not} (2)*

Reject 52
Reject 52.0
Reject 52.00 g
(d)  

<table>
<thead>
<tr>
<th>1s</th>
<th>2s</th>
<th>2p</th>
<th>3s</th>
<th>3p</th>
<th>3d</th>
<th>4s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2 marks for fully correct configuration  
1 mark if 26 electrons with 2 in 4s but the 3d electrons shown as pairs  
Ignore the way the arrow heads point in the singly occupied 3d boxes.  
Allow half arrows \( \uparrow \downarrow \) or \( | \) or \( \uparrow \) or any combination in any box  

\[ \text{Accept vertical lines in place of arrows} \quad \text{1 max} \]

[10]

68. (a)  

![Graph of first ionisation energy of the elements Li to Ne](image)

General increase, starting with carbon above boron (1)  
Dip from N to O only (1)  
\[ \text{Accept lines joining points do not need to be drawn in.} \]
\[ \text{Accept a very small drop from N to O} \]

2
(b) • The **nuclear** charge/proton number increases / becomes more positive (1)
• The (inner shell) shielding is the same/same number of inner shell electrons/ no or little increase in shielding (1)

**Either**
• **Outer** electron closer to nucleus /**atomic** radius decreases /size of atom decreases

**Or**
• electrons being removed are in same shell

**Or**
• **Outer** electrons are in same shell (1) 3

*Reject Atomic Number increasing*

(c) In boron the extra electron is in a p orbital /new sub-shell (1)

**Either**
Which has extra shielding (by the s orbital electrons)
**OR**
Which is at a higher energy (level than the s orbital in Be) (1) 2

*Accept reverse argument for beryllium*
*Reject shell for sub-shell*
*Reject answers that refer to full shell being left do not score second mark*

*Further from the nucleus*

[7]

69. (i) 112 1

(ii) \[
\frac{(188 \times 15.2) + (189 \times 17.4) + (190 \times 26.4) + (192 \times 41.0)}{100}
\]
\[= 190.3 \text{ (1)}\]

Correct answer with no working (2)
Ignore units 2

*Accept 190.34/190.342 with no working = max 1*
*Reject 190*
*Reject 190.34*
*Reject 190.342*

[3]

70. (a) (i) metallic 1

*Reject metal*

(ii) attraction between ions and delocalised electrons is stronger in lithium (1)
With reference to atoms 1 max
as lithium ion is smaller / lithium ion has greater charge
density/ electrons closer to nucleus (1)
Accept reverse argument

(b) (i)

(1)

Accept all dots and crosses
Accept charges next to element symbols
Reject correct electronic structure but wrong or no charges
max 1
Reject covalent structures = 0

(ii) Electrons are promoted (to higher energy level). (1)
Then they fall back to lower levels (they emit light
of particular wavelength). (1)

(iii) strontium / calcium

Accept rubidium

71. B
72. C

73. D

74. B

75. (a) A 1
    (b) B 1
    (c) D 1

76. (a) A Cu(g)
    B Cu⁺ (g)
    C 2Br(g)
    2 marks for all correct but max 1 if state symbols wrong/ missing
    1 mark for 2 correct
    D $H_f^{(a)}$ / (standard) enthalpy (change) of formation (of CuBr₂) (1) 3

    (b) $\Delta H_f = \Delta H_d(Cu) + E_{m1}(Cu) + E_{m2}(Cu) + 2 \times \Delta H_d(1/2 Br₂) + 2 \times E_{a1}(Br) + \Delta H_{latt}$
    OR
    Lattice energy = D–(other enthalpy changes) (1)
    Can be shown using the numbers
    $= -141.8 - (338.3 + 746 + 1958 + 2 \times 111.9 + 2 \times -342.6) = -141.8 - 2580.9$
    $= -2722.7 = -2723$ (kJ mol⁻¹) (2)
    max 1 if no multiples of 2 for Br
    max 2 (out of 3) if positive sign 3

    (c) (i) QWC
        Not 100% ionic/ has some covalent character 1
        *Reject answers where it is not clear that bonding has some intermediate character, but not entirely ionic or covalent*
(ii) Non-spherical bromide / negative ion with bulge towards copper / positive ion (1)