3.1.3.1 Ionic/covalent/metallic bonds

307 minutes

299 marks
M1. (a) (i) 

(ii) vibrate faster (1)

Or bigger amplitude or more
NOT start to vibrate or other type of motion esp. translation
Ignore rotation

(b) (i) Na + \( \frac{1}{2} \) Cl\(_2\) → NaCl (1) or Na\(^+\)Cl\(^-\)

or 2 Na + Cl\(_2\) → 2 NaCl

If NA penalise once
ignore s.s. even if wrong

(ii) from sodium (1)

Allow from sodium ion, also from metal

(c) (i) not spherical (or charge uneven or distorted) (1)

OR diagram

Do NOT allow if describe Cl\(^-\) (or Cl\(^6\)) in a polarised covalent compound

(ii) high charge / size ratio (1)

allow also high charge density
OR high charge
OR small size

(d) (i) shared (1) electron pair (1)

(ii) difference in electronegativity (1)

M2. (a) (i) Covalent (1)

(ii) Co-ordinate (1) (or dative)

(iii) Both / two / pair electrons come from nitrogen (1)
(iv) 4 bonding/electron pairs (1)

repel equally (1)

OR are identical (1)

as far apart as possible (1)

OR to position of minimum repulsion (1)

tetrahedron (1)

(b) Power (or ability) of an element/atom to attract electron pair/electrons/an electron/electron density (1)

in a covalent bond (1)

Allow attract from, withdraw in, do not allow remove from, withdraw from.

(c) (i) Electron deficient (1)

Or small, slight, partial positive charge

(ii) \( H < N \) (1)

[11]

M3.

(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</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>

or negligible

or zero

or \( 5.0 \times 10^{-4} \) to \( 5.6 \times 10^{-4} \)

if 'g' in mass column - wrong

penalise once

(b) \(^{38}\text{Ar} \) (1)(1)

Allow numbers before or after Ar

2
(c) \[ \text{S: } 1s^2 \, 2s^2 \, 2p^6 \, 3s^2 \, 3p^2 \, (1) \]

Allow upper case letters

\[ \text{S}^2-: 1s^2 \, 2s^2 \, 2p^6 \, 3s^2 \, 3p^6 \, (1) \]

If use subscript penalise once

(d) \[ \text{Block: } \text{p} \, (1) \]

Explanation: Highest energy or outer orbital is (3) p

OR outer electron, valency electron in (3) p

NOT 2p etc.

(e) (i) \[ \text{Bonding in Na}_2\text{S: ionic } (1) \]

\[ \text{Bonding in CS}_2: \text{ covalent } (1) \]

ignore other words such as dative / polar / co-ordinate

(ii) Clear indication of electron transfer from Na to S (1)

1 e\(^-\) from each (of 2) Na atoms or 2 e\(^-\) from 2 Na atoms (1)

QoL correct English

(iii) \[ \text{Correct covalent bonds } (1) \]

All correct including lone pairs (1)

Allow all \( *s \) or all \( \times s \)

M2 tied to M1

NOT separate e\(^-\)s in S\( 2- \) \( 2p \)

(iv) \[ \text{CS}_2 + 2\text{H}_2\text{O} \rightarrow \text{CO}_2 + 2\text{H}_2\text{S} \, (1) \]

Ignore state symbols even if wrong
M4. (a) (i) Electronegativity (difference) or suitable description (1)
Accept F and Cl are highly electronegative
Not both atoms are highly electronegative

(ii) HF = hydrogen bonding (1)
HCl = (permanent) dipole-dipole bonding or even van de Waals’ (1)
Hydrogen bonding stronger / is the strongest IMF (1)
Accept a statement that HF must have the stronger IMF, even if no IMFs identified
The explanation must be based on intermolecular forces/attractions
Note: if the explanation is clearly intramolecular = CE

(b) Electron pair or lone pair donated (1)
Do not accept ‘donation of electrons’
From chloride ion to Al or AlCl₃ (1)
M1 can be earned by a general explanation of coordinate bonding, even if the electron pair is said to come from Al. The second mark, M2, is for this specific bond
Ignore missing charge

(c) 

PCl₅ shown as trigonal bipyramid
PCl₄⁺ shown as tetrahedral
[Look for: ONE solid linear Cl-P-Cl bond] NO solid linear Cl-P-Cl bonds
Bond Angle(s) 90° and 120° (1) Bond angle(s) 109 or 109.5° (1)

M5. (a) (i) 1s² 2s² 2p² 3s² 3p¹ (1)
Allow subcripted electron numbers

(ii) p (block) (1)
Allow upper or lower case ‘s’ and ‘p’ in (a)(i) and (a)(ii)
(b) Lattice of metal / +ve ions/ cations / atoms (1)

   Not +ve nuclei/centres

   Accept regular array/close packed/tightly packed/uniformly arranged

(Surrounded by) delocalised electrons (1)

Note: Description as a ‘giant ionic lattice’ = CE

(c) Greater nuclear or ionic charge or more protons (1)

   Smaller atoms / ions (1)

   Accept greater charge density for either M1 or M2

   More delocalised electrons / e\(^-\) in sea of e\(^-\) / free e\(^-\) (1)

   Stronger attraction between ions and delocalised / free electrons etc. (1)

      Max 3

      Note: ‘intermolecular attraction/ forces’ or covalent molecules = CE

      Accept stronger ‘electrostatic attraction’ if phrase prescribed elsewhere

      Ignore references to m/z values

      If Mg or Na compared to Al, rather than to each other, then: Max 2

      Treat description that is effectively one for Ionisation Energy as a ‘contradiction’

(d) (Delocalised) electrons (1)

   Move / flow in a given direction (idea of moving non-randomly)

   or under the influence applied pd QoL mark (1)

   Allow ‘flow through metal’

   Not: ‘Carry the charge’; ‘along the layers’; ‘move through the metal’

M6. (a) \(4\text{LiH} + \text{AlCl}_3 \rightarrow \text{LiAlH}_4 + 3\text{LiCl}\)

1

(b) \(\text{H}^- = 1\text{s}^2\) or \(1\text{s}\)

1
(c) Tetrahedral or diagram
   \(\text{Not distorted tetrahedral}\)

   \((\text{Equal}) \text{ repulsion}\)

   between four bonding pairs / bonds
   \(\text{Not repulsion between H atoms loses M2 and M3}\)
   \(\text{Not ‘separate as far as possible’}\)
   \(\text{‘4’ may be inferred from a correct diagram}\)

(d) Dative (covalent) or coordinate

Lone pair \textbf{or} non-bonding pair of electron \textbf{or} both e⁻

\textbf{QoL} Donated from H⁻ to Al \textbf{or} shared between H and Al
   \((\text{tied to M2})\)
   \(\text{Not ‘from H atom’} \text{ (Not ‘to Al ion’) (Not ‘e’s transferred’})\)
M7. QoL Bonding Both covalent
(linked statement)

Structure Iodine = molecular /I₂ (stated or in diagram)
[treat incorrect diagram as contradiction]

Diamond = giant molecular/macromolecular/giant covalent / giant atomic (stated only)
Reference to van der Waals’/dipole-dipole = contradiction

QoL Iodine Weak van der Waals’ forces / induced dipole-induced dipole

Diamond Covalent bonds would need to be broken

Many / strong covalent bonds OR much energy needed
Tied to M5 or near miss
[If ionic/metallic structure suggested then CE for that substance]
[If hydrogen bonding suggested, for I₂ lose M2 & M4; for diamond lose M3,M5&M6]

M8. (a) (i) Electron transfers from Mg to Cl/Mg loses e⁻ and Cl gains e⁻

Mg loses 2e⁻, each Cl gains 1e⁻
(Marks can be awarded from diagrams/equations)

(ii) Electrostatic attractions / attractions between oppositely charged ions
(molecules = CE = 0)

Are strong or require much energy to overcome
Tied to M1
‘Ionic bonds are strong’ score 1 mark
(b) (i) Tendency / strength / ability / power of an atom/ element / nucleus to attract / withdraw electrons / e\textsuperscript{-} density / bonding pair / shared pair In a covalent bond 
   (tied to M1 - unless silly slip in M1) 
   (If molecule/ion then = CE = 0) 
   (NOT electron (singular) for M1) 

(ii) Increasing proton number / nuclear charge 
     (NOT atomic number) 
     Decreasing size / same shielding / same shells 

(c) (i) Electron cloud/distribution (around anion) 
   Is distorted or is unequally distributed 
   Marks may be awarded from diagrams 
   ‘Chloride ion is distorted’ scores 1 mark 
   (Reference to dipoles or polarised bond = CE) 

(ii) Smaller size 
     (Ignore m/z references) 
     Higher charge or 3\textsuperscript{-}/2\textsuperscript{-} specified 
     (‘Higher charge density scores 1 mark if neither mark awarded above) 

(iii) Covalent / covalent character / polar covalent / coordinate / dative 
     [NOT ionic with covalent character] 

M9. (a) dative / coordinate (covalent) bond; 
     Lone/non-bonding pair / both electrons; 
     (donated) from P to H\textsuperscript{+};
(b) \( \text{PH}_3 \) \hspace{1cm} \text{PH}^+ \\

\begin{align*}
\text{H} & \text{P} & \text{H} \\
\text{H} & & \text{H} \\
\end{align*}

\begin{align*}
\text{H} & \text{P} & \text{H} \\
\text{H} & & \text{H} \\
\end{align*}

Pyramidal OR trigonal pyramid 109(1/2)°; 
(accept tetrahedral)

M10. 

(i) \( \text{BF}_3 \)  
Trigonal planar/planar triangular  
[Not plane triangle]

\( \text{BF}_4^- \)  
Tetrahedral  
[Not distorted tetrahedral]

Equal repulsion between (4) bonding pairs/bonds/bonding electrons

109(1/2)°
(ii) Lone pair donated / both electrons supplied by one atom

from F\(^{-}\) (to B)

[ignore missing charge or fluorine or ‘atom’]


dative/dative covalent/coordinate bonding

M11.

(a)

[Diagrams must be complete and accurate]

(b) (i) Attraction /electrostatic forces/bonds/attractions between (positive) ions/lattice and delocalised/free electrons/sea of electrons.

[Not metallic bonding]
[Not just ‘forces’]

(ii) Electrostatic attractions/forces between ions or attractions between (oppositely charged) ions/ Na\(^{+}\) & Cl\(^{-}\)

[Not ionic bonding]

(iii) (Here) the ionic bonding in NaCl is stronger/requires more energy to break than the metallic bonding in Na

QoL Accept ‘bonding/forces of attraction in NaCl is stronger than in Na’

[If IMF/molecules/van der Waals/dipole–dipole mentioned in parts(i) or (ii), then CE = 0 for parts (i) and/or(ii) and CE = 0 for part(iii)]
(c) Comparison:
Sodium conducts and sodium chloride does NOT conduct

Allow 'only Na conducts'
Accept 'Na conducts, NaCl only conducts when molten'
[Do not accept sodium conducts better than sodium chloride etc.]

Explanation:
(Delocalised) electrons flow though the metal

Allow e⁻ move/carry current/are charge carriers/transfer charge.
[Not 'electrons carry electricity']
[Not 'NaCl has no free charged particles']

Ions can't move in solid salt

(d) Layers can slide over each other – idea that ions/atoms/particles move
[Not molecules]
[Not layers separate]

(e) (i) 
<table>
<thead>
<tr>
<th></th>
<th>Na</th>
<th>Cl</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21.6</td>
<td>33.3</td>
<td>45.1</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>35.5</td>
<td>16</td>
</tr>
</tbody>
</table>

|   | 0.9(39) | 0.9(38) | 2.8(2) |
Hence: 1 1 3
Accept backwards calculation, i.e. from formula to % composition, and also accept route via Mr to 23; 35.5; 48, and then to 1:1:3
[If % values incorrectly copied, allow M1 only]
[If any wrong Aᵣ values/atomic numbers used = CE = 0]

(ii) \( 3\text{Cl}_2 + 6\text{NaOH} \rightarrow 5\text{NaCl} + \text{NaClO}_3 + 3\text{H}_2\text{O} \)
M12. (a) NaCl is ionic cubic lattice ions placed correctly electrostatic attraction between ions Covalent bonds between atoms in water Hydrogen bonding between water molecules Tetrahedral representation showing two covalent and two hydrogen bonds 2 hydrogen bonds per molecule Attraction between ions in sodium chloride is very strong Covalent bonds in ice are very strong Hydrogen bonds between water molecules in ice are much weaker Consequently, less energy is required to break the hydrogen bonds in ice to form separate water molecules than to break the ionic bonds in sodium chloride and make separate ions
4 bonding electron pairs
and one lone pair
gen and one lone pair
repel as far apart as possible
QWC
lone pair - bond pair repulsion > bp—bp QWC
pushes S-F bonds closer together
shape is trigonal bipyramidal with lone pair either
axial or equatorial QWC
angles <90
and < 120

[20]
M13. (a) Ability/power of an atom/element/nucleus to withdraw electron density or electron cloud or a pair of electrons (towards itself);
   *Not withdraw an electron*
   *If ref to ionic, metallic, imf etc then CE = 0*

   From a covalent bond or from a shared pair of electrons;
   *Not distort*
   *Not remove electrons*

(b) Van der Waals/ vdw/London/ temporary (induced) dipole/ dispersion forces;

   Hydrogen bonds/H bonds;
   *Not just hydrogen*

(c) (Large) electronegativity difference between N + H/ difference of 0.9/ N very electronegative;
   *Insufficient to say N= 3.1 and H = 2.1*

   Forms N $\delta-$ / H $\delta+$ or dipole explained in words;
   *Not N becomes (fully) negative or vice versa*

   Lone pair on N attracts/forms weak bonds with H ($\delta+$);
   *QWC*
   *Can score M2 and 3 from a diagram*

(d) Co-ordinate/dative;
   *If not correct then CE = 0. If covalent/blank mark on.*

   Both electrons/ lone pair (on P/PH$_3$)
   *Not lone pair on hydrogen*

   Shares/donated from P(H$_3$)/ to H($\delta+$);

(e) 3 bonds and 1 lp attached to As;
   *Must label H and As atoms*
   *Accept distorted tetrahedral not bent tetrahedral*

   Pyramidal/tetrahedral/ trigonal pyramidal;
   *Not bipyramidal/triangular*
(f) (Only) weak Van der Waals forces between molecules /AsH₃
has weaker IMF /ammonia has hydrogen bonding/ more
energy needed to break IMF’s in ammonia/ Van der Waals
weaker than H bonds;
    Accept has no H bonds.
    Ignore dp-dp in AsH₃ provided ammonia has stronger IMF.
    If between atoms mentioned CE=0
    Break bonds CE = 0

(g) 4AsCl₃ + 3NaBH₄ → 4AsH₃ + 3NaCl + 3BCl₃
Accept multiples

M14.  
(a) (i) Average/mean mass of 1 atom (of an element);
    Average mass of 1 atom × 12.
    Mass 1/12 atom of ¹²C;
    Mass 1 atom of ¹²C.
    QWC.

(ii) Other isotope = 46.0%;
    107.9 = \(\frac{54 \times 107.1 + (46 \times ?)}{100}\);
    M2 whole expression.
    108.8;
    Answer 108.8 (3 marks).
    Answer min 1 d.p..

    Same electronic configuration/ same number of electrons (in
outer shell)/ both have 47 electrons;
    Ignore protons and neutrons unless incorrect.
    Not just electrons determine chemical properties.
(b) Ionisation;

high energy electrons fired at sample;

   Allow electron gun / blasted with electrons.

Acceleration;

With electric field/ accelerating potential/ potential difference;

   Allow by negative plate.

Deflection;

With electromagnet/ magnet/ magnetic field;

   M2 dependent on M1.
   M4 dependent on M3.
   M6 dependent on M5.

(c) (Silver) metallic (bonding);

   Vdw/molecules CE=0.

   Regular arrangement of same sized particles;

   + charge in each ion;

      Ignore multiple positive charges.
      Candidates do not need to show delocalised electrons.

(d) Ionic (bonds);

   Minimum 4 ions shown in 2D square arrangement placed Correctly;

      Do not allow multiple charges on ions.

   Further 3 ions shown correctly in a cubic lattice;

   Strong (electrostatic) forces/bonds;

      If vdw/molecules/covalent mentioned CE = 0 for M4 and M5.

   Between + and – ions:

      Accept between oppositely charged ions.
M15.  

(a)  

(i)  Covalent;  
\[ \text{If not covalent CE = 0.} \]
\[ \text{If blank, mark on.} \]

Shared pair of electrons (one from each atom);  
\[ \text{Not shared electrons.} \]

(ii) Hydrogen bonds / H bonds;  
\[ \text{Not just hydrogen.} \]

Van der Waals/London/dispersion forces/temporary induced dipole;

(b)  

Showing all the lone pairs on both molecules;  
\[ \text{Allow showing both lone pairs on the O involved in the H-bond.} \]

Showing the partial charges on O and H on both molecules;  
\[ \text{Allow showing both partial charges on the O and H of the other molecule involved in the H bond.} \]

Showing the Hydrogen bond from the lone pair on O of one molecule to the delta + on the H of the other molecule;

(c)  

(i)  
\[ \text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}; \]
\[ \text{Accept multiples.} \]
\[ \text{Allow C}_2\text{H}_6\text{O}. \]

(ii) CO is (produced which is) toxic/ poisonous/C (may be produced) which is toxic/ C is a respiratory irritant/ C (particles) exacerbate asthma/C causes global dimming/ smog;  
\[ \text{Must relate to C or CO.} \]
\[ \text{Any mention of SO}_2\text{ NO}_2 \text{ or other pollutants CE = 0.} \]

(iii) More fuel needed (which costs more)/Wastes fuel/ less fuel burnt (so need more to buy more)/engine gets sooty so need to pay for engine to be cleaned/Have to fit catalytic converter;  
\[ \text{Not just costs more.} \]
\[ \text{Not engine gets sooty unless qualified.} \]
(d) (i) (React) with CaO/ calcium oxide/quicklime/lime;
   \( \textit{Accept CaCO}_3/ \text{calcium carbonate/limestone.} \)
   \( \textit{Not chalk.} \)

   \( \text{All the sulfur dioxide may not react with the CaO or CaCO}_3/ 
   \text{may not have time to react/ incomplete reaction;} \)
   \( \textit{Accept incomplete reaction.} \)

   \( \text{(ii) Occupies a (much) smaller volume;} \)
   \( \textit{Not easier to store or transport.} \)

M16. (a) \( 2s^2 \ 2p^6; \)

   \( \text{If ignored the} \ 1s^2 \ \text{given and written} \ 1s^22s^22p^6 \ \text{mark as correct} \)
   \( \text{Allow capitals and subscripts} \)

   \( \text{(b) (i)} \ \text{Na}^+(g) \rightarrow \text{Na}^{2+}(g) + e^{(-)}; \)
   \( \text{One mark for equation and one mark for state symbols} \)

   \( \text{Na}^+(g) + e^{(-)} \rightarrow \text{Na}^{2+}(g) + 2e^{(-)}; \)
   \( \text{M2 dependent on M1} \)
   \( \text{Allow Na}^+(g) - e^{(-)} \rightarrow \text{Na}(g) \)
   \( \text{Allow X}^+(g) \rightarrow X^{2+}(g) + e = 1 \ \text{mark} \)

   \( \text{(ii) Na}^{(2+)} \ \text{requires loss of e}^{-} \ \text{from a} \ 2(p) \ \text{orbital or} \ 2^{\text{nd}} \ \text{energy level or} \)
   \( \text{2^{nd} shell and Mg}^{(2+)} \ \text{requires loss of e}^{-} \ \text{from a} \ 3(s) \ \text{orbital or} \ 3^{\text{rd}} \ \text{energy level or} \ 3^{\text{rd}} \ \text{shell/} \ 
   \text{Na}^{(2+)} \ \text{loses e from a lower (energy) orbital/ or vice versa;} \)
   \( \text{Not from 3p} \)
   \( \text{Less shielding (in Na);} \)
   \( \text{Or vice versa for Mg} \)

   \( \text{e}^{-} \ \text{closer to nucleus/ more attraction (of electron to nucleus) (in Na);} \)
   \( \text{M3 needs to be comparative} \)

   \( \text{(iii) Aluminium /Al;} \)

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(c) Decreases;
   \[\text{If not decreases } CE = 0\]
   \[\text{If blank, mark on}\]
   Increasing nuclear charge/ increasing number of protons;
   1

Electrons in same shell or level/ same shielding/ similar shielding;
1

(d) Answer refers to Na;
   \[\text{Allow converse answers relating to Mg.}\]

Na fewer protons/smaller nuclear charge/ fewer delocalised electrons;
   \[\text{Allow Mg is } 2^+ \text{ and Na is } +.\]
   \[\text{If vdw } CE = 0.\]

Na is a bigger ion/ atom;
1

Smaller attraction between nucleus and delocalised electrons;
   \[\text{If mentioned that charge density of } Mg^{2+} \text{ is greater then allow first 2 marks.}\]
   \[\text{(ie charge / size / attraction).}\]
   \[\text{M3 allow weaker metallic bonding.}\]
1

(e) (Bent) shape showing 2 lone pairs + 2N–H bond pairs;
   \[\text{Atoms must be labelled.}\]
   \[\text{Lone pairs can be with or without lobes.}\]
1

Bent / v shape/ triangular;
   \[\text{Not tetrahedral.}\]
   \[\text{Allow non-linear.}\]
   \[\text{Bent-linear = contradiction.}\]
1

(f) Ne has full sub-levels/ can’t get any more electrons in the sub-levels/ Ne has full shells;
   \[\text{Not } 2s^2 2p^6 \text{ alone.}\]
   \[\text{Not stable electron configuration.}\]
1

M17. (a) Hydrogen/H bonds
   \[\text{Not just hydrogen}\]
   1

   van der Waals/vdw/dipole-dipole/London/temporarily induced dipole/dispersion forces
   \[\text{Not just dipole}\]
   1
M1 for partial charges as indicated in diagram (correct minimum)
M2 for all four lone pairs
M3 for H bond from the lp to the H (δ+) on the other molecule
Lone pair on hydrogen CE = 0
OHO CE = 0
If only one molecule of water shown
CE = 0

(c) Hydrogen bonds/IMF (in water) stronger

OR

IMF/VDW/dipole-dipole forces (in H\textsubscript{2}S) are weaker

OR

H bonding is the strongest IMF

Ignore energy references
Comparison must be stated or implied

(d) Atoms/molecules get larger/more shells/more electrons/more surface area

Not heavier/greater Mr

therefore increased Van der Waals/IMF forces

Ignore references to dipole-dipole forces

(e) Dative (covalent)/coordinate

If not dative/coordinate CE = 0/2
If covalent or blank read on

(Lone) pair/both electrons/two electrons on O(H\textsubscript{2}) donated (to H\textsuperscript{+})
OR pair/both electrons come from O(H\textsuperscript{2+})

Explanation of a coordinate bond specific to oxygen or water required
Not just H\textsuperscript{+} attracted to lone pair since that is nearer to a H bond
(f) ionic

\[ \text{if not ionic CE} = 0 \]

oppositely charged ions/\(+ \) and \(- \) ions or particles

atoms or molecules loses M2 and M3

ions attract strongly OR strong/many (ionic) bonds must be broken

\[ S^\text{-} \text{loses M2} \]

Reference to IMF loses M2 and M3

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M18. (a) (i) shared pair of electrons

Can have one electron from each atom contributes to the bond

Not both electrons from one atom

(ii) \[ \frac{1}{2} \text{Cl}_2 + \frac{3}{2} \text{F}_2 \rightarrow \text{ClF}_3 \]

Only

Ignore state symbols even if wrong

(b)
Allow any structure with 4 bp
In CClF₂, watch for Cl in centre - it must be C
Ignore wrong bond angles
Representations of lone pairs allowed are the two examples shown with or without the electrons in the lobe. Also they can show the lone pair for either structure by two crosses/dots or a line with two crosses/dots on it e.g.

Or a structure with 3 bp and 2 lp

(c) Dipole – dipole
Allow van der Waals/vdw/London/dispersion/temporary dipole – induced dipole
Not dipole alone

(d) (i) Coordinate/dative (covalent)
If wrong CE = 0/3 but if 'covalent' or left top line blank, mark on.

(Lone) pair of electrons/both electrons (on F⁻)
CE if lone pair is from B
Donated from F⁻/fluoride or donated to the BF₃
Must have the – sign on the F i.e F⁻
Ignore F⁻
M3 dependent on M2

(ii) 109° to 109.5°
(e) \[
\frac{238 \times 100}{438}
\]  
For 1 mark allow 238 as numerator and 438 as denominator or correct strings  

= 54.3%  
2 marks if correct answer to 3 sig figs.  
54% or greater than 3 sig figs = 1 mark  

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M19.  

(a) Macromolecular/giant covalent/giant molecular/giant atomic  
If IMF/H-bonds/ionic/metallic CE = 0/3  
covalent bond between molecules CE = 0/3  
If giant unqualified M1 = 0 but mark on  

Many/strong covalent bonds  
M2 and M3 can only be scored if covalent mentioned in answer  
Ignore metalloid and carbon  
Ignore bp  

Bonds must be broken/overcome  
Ignore numbers of bonds and references to energy  

(b) (Simple) molecular  
QoL  
Do not allow simple covalent for M1  
Giant covalent/ionic/metallic, CE = 0  
If breaking covalent bonds CE= 0/3  

S bigger molecule (than P) or S_8 and P_4 references  
QoL  
Allow more electrons in sulfur molecule or S_8  
Do not allow S is bigger then P  
Allow S molecule has a bigger M  
Do not allow contradictions  

So more/stronger van der Waals' forces (to be broken or overcome)  
Not just more energy to break
(c) Regular arrangement of minimum of 6 particles in minimum of 2 rows
   
   Ignore e–
   Do not allow ring arrangements OR structures bonded with electrons

   + charge in each one (of 6)
   Allow +, (1+, 2+ or 3+) in ions/or in words

   Rows/planes/sheets/layers (of atoms/ions) can slide (owtte) over one another
   
   M3 independent
   If ionic bonding/molecules/IMF/vdw/covalent, penalise M3
   Ignore layers of electrons sliding

(d) Bigger charge (3+ compared to 1+)
   
   CE = 0 if molecules, ionic, covalent, IMF
   (Allow A²⁺)

   OR smaller atom/ion in Al/more protons/bigger nuclear charge

   More free/delocalised electrons (in Al)/bigger sea of electrons in Al
   Accept 2 or 3 delocalised electrons compared to 1 in Na

   Stronger metallic bonding/stronger (electrostatic) attraction between the (+) ions or nuclei and the (delocalised) electrons (or implied)
   Must be implied that the electrons are the delocalised ones not the electrons in the shells.
   Accept converse arguments

M20. (a) Water or H₂O or molecules (in ice) are held further apart (than in liquid water)/(more) space/gaps/holes in structure/Water or H₂O or molecules (in ice) are more spread out

   Allow water (liquid) is more compact/less space/gaps/holes
   CE if holes filled with air, O₂ etc
   CE if macromolecule
   CE if atoms further apart (since ambiguous)
   Ignore spaces filled with H₂O
   Ignore reference to H bonds
   Allow better tessellation in liquid water
(b)  
(i) Hydrogen bonding  
   Allow H bonds  
   Do not allow 'hydrogen' only but mark on  
   
(ii) Van der Waals/VdW  
   Allow London forces, dispersion forces, temporary induced dipole forces  
   
(iii) Hydrogen bonding is stronger (than van der Waals forces)/IMF in ice stronger (than IMF in methane)/H bonds take more energy to break  
   Not H Bonds are strong (needs comparison)  
   If (b)(i) OR (ii) is incorrect, cannot award (b)(iii)  
   If (b)(i) and/or (ii) is blank, can score (b)(iii)  
   
(c)  
(i) Structure showing 3 bonds to H and 1 lone pair  
   (trigonal) pyramid(al)/(distorted) tetrahedral  
   do not insist on the + sign  
   Allow triangular pyramid  
   Not square pyramid  
   Ignore bond angles in structure  
   M2 independent of M1  
   
(ii) 107°  
   Allow range 106 – 108°  
   Ignore °(C)  
   
(iii) NH₃/ammonia  
   Contradictions (eg NH₄ ammonia) CE = 0  
   
(d) 3  
   Allow three/III/3 lone pairs/3lp/3 lone pairs of electrons  

M21.  

(a) Covalent  
   If not covalent CE = 0/2  
   If dative covalent CE = 0/2  
   If blank mark on  
   Ignore polar  
   If number of pairs of electrons specified, must be 3
Shared pair(s) of electrons / one electron from Br and one electron from F
Not 2 electrons from 1 atom
Not shared pair between ions/molecules

\[
\begin{align*}
\text{BrF}_3 & \text{ should have 3 bp and 2 lp and correct atoms for the mark} \\
\text{BrF}_4^- & \text{ should have 4 bp and 2 lp and all atoms for the mark (ignore sign)}
\end{align*}
\]

\[
\begin{align*}
\text{BrF}_3 & \text{ if trigonal planar shown } = 120^\circ \\
& \text{ Allow 84 – 90° or 120° and ignore 180°} \text{ or if T shape shown 84 – 90°} \\
& \text{Irrespective of shape drawn}
\end{align*}
\]

\[
\begin{align*}
\text{BrF}_4^- & 90^\circ \\
& \text{ Only} \\
& \text{Ignore 180°}
\end{align*}
\]

(c) Ionic or (forces of) attraction between ions / bonds between ions
If molecules, IMF, metallic, CE =0
If covalent bonds mentioned, 0/3, unless specified within the BrF$_4^-$ ion and not broken
Ignore atoms

Strong (electrostatic) attraction / strong bonds / lots of energy needed to break bonds
Between K\(^+\) and BrF\(_4^-\) ions/oppositely charged ions / + and – ions

If ions mentioned they must be correct
Strong bonds between + and – ions =3/3

(d) (i) Hydrogen bonds/hydrogen bonding/H bonds/H bonding

Not just hydrogen

(ii)

\[ \text{\(\delta^+\)} \quad \text{\(\delta^-\)} \quad \text{\(\delta^+\)} \quad \text{\(\delta^-\)} \]

\[ \text{H} \quad \text{---} \quad \text{H} \]

One mark for 4 partial charges
One mark for 6 lone pairs
One mark for H bond from the lone pair to the H\(\delta^+\)

Allow F\(_2\)

If more than 2 molecules are shown they must all be correct.
Treat any errors as contradictions within each marking point.
CE = 0/3 if incorrect molecules shown.

(e) vdw / van der Waals forces between molecules

QoL

Not vdw between HF molecules, CE = 0/2
vdw between atoms, CE = 0/2
If covalent, ionic, metallic, CE=0/2

IMF are weak / need little energy to break IMF / easy to overcome IMF

M22. (a) (i) Macromolecular / giant covalent / giant molecular / giant atomic

If covalent, molecular, giant, lattice, hexagonal or blank mark on.
If metallic, ionic or IMF chemical error CE = 0 for (a)(i), (a)(ii) and (a)(iii).

(ii) Delocalised electrons / free electrons

Able to move / flow (through the crystal)

Allow M2 for electrons can move / flow.

Ignore electrons can carry a current / charge.

(iii) Covalent bonds
Many /strong/ hard to break / need a lot of energy to break
M2 dependent on M1.
Ignore van der Waals' forces.

(b) (i) (Giant) metallic / metal (lattice)
If FCC or BCC or HCP or giant or lattice, mark on.
If incorrect (b)(i), chemical error CE for (b)(ii) and (c)(ii).

(ii) Nucleus / protons / positive ions and delocalised electrons (are attracted)
QWC Must be delocalised electrons – not just electrons.
Chemical error = 0/2 for (b)(ii) if other types of bonding or IMF mentioned.

Strong attraction
Allow strong metallic bonding for one mark if M1 and M2 are not awarded.

(c) (i) Layers of atoms/ions slide (over one another)
Do not allow just layers.

(ii) (Strong) (metallic) bonding re-formed / same (metallic) bonding / retains same (crystal) structure / same bond strength / same attraction between protons and delocalised electrons as before being hammered or words to that effect
If IMF, molecules, chemical error CE = 0/1 for (c)(ii).
If metallic not mentioned in (b)(i) or (b)(ii) it must be mentioned here in (c)(ii) to gain this mark.
Do not allow metallic bonds broken alone.
Ignore same shape or same strength.

(d) (giant) Ionic
If not ionic, chemical error CE = 0/3

Between + and – ions / oppositely charged ions or Mg\(^{2+}\) and O\(^{2-}\)
If molecules mentioned in explanation lose M2 and M3
Allow one mark for a strong attraction between incorrect charges on the ions.

Strong attraction
M23.  

(a) 

Need to see 3 P–H bonds and one lone pair (ignore shape).

(b) Coordinate / dative

If not coordinate / dative then chemical error CE=0 unless blank or covalent then M1 = 0 and mark on.

Pair of electrons on P(\(\text{H}_3\)) donated (to H\(^+\))

Do not allow a generic description of a coordinate bond.

(c) \(109.5^\circ / 109\frac{1}{2} / 109^\circ 28'\)

Allow answers in range between 109° to 109.5°

(d) Difference in electronegativity between P and H is too small

Allow P not very electronegative / P not as electronegative as N, O and F / P not electronegative enough / P not one of the 3 most electronegative elements.

Do not allow phosphine is not very electronegative.

[5]

M24.  

(a) (i) The power of an atom or nucleus to withdraw or attract electrons OR electron density OR a pair of electrons (towards itself)

Ignore retain

In a covalent bond

(ii) More protons / bigger nuclear charge

Same or similar shielding / electrons in the same shell or principal energy level / atoms get smaller

Not same sub–shell

Ignore more electrons

(b) Ionic

If not ionic then CE = 0 / 3

If blank lose M1 and mark on
Strong or many or lots of (electrostatic) attractions (between ions)

*If molecules / IMF / metallic / atoms lose M2 + M3, penalise incorrect ions by 1 mark*

Between + and − ions / between Li⁺ and F⁻ ions / oppositely charged ions

*Allow strong (ionic) bonds for max 1 out of M2 and M3*

(c) Small electronegativity difference / difference = 0.5

*Must be comparative*

*Allow 2 non-metals*

(d) (i) (simple) *molecular*

*Ignore simple covalent*

(ii) \[
\text{OF}_2 + \text{H}_2\text{O} \rightarrow \text{O}_2 + 2\text{HF}
\]

*Ignore state symbols*

*Allow multiples*

*Allow \(\text{OF}_2\) written as \(\text{F}_2\text{O}\)*

(iii) 45.7% O

\[
\begin{array}{ll}
\text{O} & \text{F} \\
45.7 & 54.3 \\
16 & 19
\end{array}
\]

*If students get \(\text{M2}\) upside down lose \(\text{M2} + \text{M3}\)*

*Check that students who get correct answer divide by 16 and 19 (not 8 and 9). If dividing by 8 and 9 lose \(\text{M2}\) and \(\text{M3}\) but could allocate \(\text{M4}\) ie max 2*

\[
\begin{array}{ll}
2.85 & 2.85 \\
1 & 1
\end{array}
\]

\[\text{EF} = \text{OF} \text{ or } \text{FO}\]

*Calculation of \(\text{OF}\) by other correct method = 3 marks*

*Penalise \(\text{Fl}\) by 1 mark*

\[
\text{MF} = \frac{70.0}{35} = \text{O}_2\text{F}_2 \text{ or } \text{F}_2\text{O}_2
\]

M25. (a) \[
\text{Al} + 1.5\text{Cl}_2 \rightarrow \text{AlCl}_3
\]

*Accept multiples.*

*Also \(2\text{Al} + 3\text{Cl}_2 \rightarrow \text{Al}_2\text{Cl}_6\)*

*Ignore state symbols.*
(b) Coordinate / dative (covalent)
   If wrong CE=0/2 if covalent mark on.

   **Electron pair on Cl\(^-\) donated to Al(Cl\(_3\))**

   **QoL**
   Lone pair from Cl\(^-\) not just Cl
   Penalise wrong species.

(c) Al\(_2\)Cl\(_6\) or AlBr\(_3\)
   Allow Br\(_3\)Al or Cl\(_6\)Al
   Upper and lower case letters must be as shown.
   Not 2AlCl\(_3\)

(d) SiCl\(_4\) / silicon tetrachloride
   Accept silicon(4) chloride or silicon(IV) chloride.
   Upper and lower case letters must be as shown.
   Not silicon chloride.

(e) Trigonal bipyramid(al)

(f) (i) Cl — Tl — Cl
   Accept this linear structure only with no lone pair on Tl

(ii) (Two) bonds (pairs of electrons) repel equally / (electrons in) the bonds repel to be as far apart as possible
   Dependent on linear structure in (f)(i).
   Do not allow electrons / electron pairs repel alone.
(g) Second

M26. (a) Giant covalent / giant molecular / macromolecular

Not giant alone.
Not covalent alone.

(b) Shared pair of electrons / one electron from each C atom

(c) No delocalised / free / mobile electrons

Allow all (outer) electrons involved in (covalent) bonds.
Ignore ions.

(d) CH

Allow HC
C and H must be capital letters.