F321: Atoms, Bonds and Groups
Structure & Bonding – Mark Scheme

1. (i) (Electrostatic) attraction between oppositely charged ions. ✓
   - IGNORE force
   - IGNORE references to transfer of electrons
   - MUST be ions, not particles

   (ii) Mg shown with either 8 of 0 electrons
   - AND
   - S shown with 8 electrons with 2 crosses and 6 dots (or vice versa) ✓
   - Correct charges on both ions ✓

   \[
   \begin{array}{c}
   \text{Mg}^{2+} \\
   \text{S}^{2-}
   \end{array}
   \]
   - Mark charges on ions and electrons independently
   - *For first mark*, if 8 electrons are shown around the Mg then ‘extra electrons’ around S must match the symbol chosen for electrons around Mg
   - Shell circles not required
   - IGNORE inner shell electrons
   - Brackets are not required

2. (i) Electron pairs in covalent bonds shown correctly using dots and crosses in a molecule of the F₂O ✓
   - Lone pairs correct on O and both F atoms ✓

   \[
   \begin{array}{cccc}
   & \text{O} & \text{F} & \text{F} \\
   \end{array}
   \]
   - Must be ‘dot-and-cross’
   - circles for outer shells NOT needed
   - IGNORE inner shells
   - Non-bonding electrons of O do not need to be shown as pairs
   - Non-bonding electrons of F do not need to be shown as pairs

ALLOW 103 – 105° (103° is the actual bond angle)

There are 2 bonded pairs and 2 lone pairs ✓
Lone pairs repel more than bonded pairs ✓

ALLOW responses equivalent to second marking point. e.g.
There are 4 pairs of electrons and 2 of these are lone pairs
ALLOW ‘bonds’ for ‘bonded pairs’
DO NOT ALLOW ‘atoms repel’
DO NOT ALLOW electrons repel
ALLOW LP for ‘lone pair’
ALLOW BP for bonded pair
ALLOW LP repel more if bonded pairs have already been mentioned

3

3. (i) (At least) two NH₃ molecules with correct dipole shown with at least one H with δ⁺ and one N with δ⁻ ✓

DO NOT ALLOW first mark for ammonia molecules with incorrect lone pairs
DO NOT ALLOW first mark if H₂O, NH₂ or NH is shown

(Only) one hydrogen bond from N atom on one molecule to a H atom on another molecule ✓

ALLOW hydrogen bond need not be labelled as long as it clear the bond type is different from the covalent N–H bond
ALLOW a line (i.e. looks like a covalent bond) as long as it is labelled ‘hydrogen bond’

Lone pair shown on the N atom and hydrogen bond must hit the lone pair ✓

Hydrogen bond

ALLOW 2-D diagrams
ALLOW two marks if water molecules are used. One awarded for a correct hydrogen bond and one for the involvement of lone pair

3
(ii) Liquid H₂O is denser than solid ✓
In solid state H₂O molecules are held apart by hydrogen bonds
OR ice has an open lattice ✓

ORA
ALLOW ice floats for first mark

OR
H₂O has a relatively high boiling point OR melting point ✓
ALLOW higher melting OR boiling point than expected
DO NOT ALLOW H₂O has a high melting / boiling point

(relatively strong) hydrogen bonds need to be broken
OR a lot of energy is needed to overcome hydrogen bonds
OR hydrogen bonds are strong ✓
ALLOW other properties caused by hydrogen bonding not
mentioned within the specification
E.g. high surface tension – strong hydrogen bonds on the
surface

4. Mg has a giant structure ✓
Metallic OR delocalised seen spelt correctly at least ONCE

Mg has metallic bonding OR description of metallic bonding as positive ions
and delocalised electrons ✓
(There is electrostatic attraction between) positive ions and electrons ✓
DO NOT ALLOW as label nuclei OR protons for positive ions
ALLOW labelled diagram of metallic bonding for second and
third marks

Mg

positive ions
delocalised electrons

Lattice must have at least two rows of positive ions. If a Mg ion
is shown it must correct charge
ALLOW for labels: + ions, positive ions, cations
DO NOT ALLOW as label nuclei OR protons for positive ions
ALLOW e⁻ or e as label for electron
DO NOT ALLOW ‘–’ without label for electron

Cl has a simple molecular OR simple covalent (lattice) ✓
Covalent OR molecule OR molecular seen spelt correctly at
least ONCE
ALLOW Cl is a (covalent) molecule
Cl has van der Waals’ forces (between molecules)  
OR  
Cl has instantaneous dipole–induced dipoles  
OR  
temporary dipole–temporary dipole ✓  

**IGNORE Cl has intermolecular bonding**

van der Waals’ forces are weak **and** metallic bonds are strong  
OR  
van der Waals’ forces are weaker than metallic bonds  
OR  
Less energy is needed to overcome van der Waals’ than metallic bonds ✓

**ALLOW ECF from incorrect descriptions of giant structure with strong bonds; e.g. Mg has giant ionic structure**

**ALLOW ECF from any incorrect intermolecular forces e.g. permanent dipole–dipole from marking point 5**

**ALLOW vdW easier to break**

**ORA**

5. giant covalent (lattice) ✓

layers ✓

**Each of the three properties below must be linked to explanation**

good conductor – because it has mobile electrons OR
delocalised electrons OR electrons can move ✓

high melting / boiling point – because strong OR

covalent bonds have to be broken ✓

soft – because there are van der Waals’ forces OR

intermolecular forces OR weak bonds OR weak forces between the layers

OR

soft – because layers can slide ✓

**Use annotations with ticks, crosses etc. for this part.**

**All five marking points are independent**

**ALLOW giant atomic OR giant molecular OR**

macromolecular

**ALLOW planes OR sheets**

Allow diagram showing at least two layers

**Electron(s) must be spelt correctly ONCE**

**DO NOT ALLOW ‘strong ionic bonds’ OR strong metallic bonds.**
6. (i) a shared pair of electrons ✓
   ALLOW any response that communicates electron pair
   ALLOW shared pairs

   (ii) Must be ‘dot-and-cross’
        circles for outer shells NOT needed
        IGNORE inner shells
        Non-bonding electrons of N do not need to be shown as a pair

   (iii) Shape: pyramidal OR (trigonal) pyramid ✓
        Explanation:
        There are 3 bonded pairs and 1 lone pair ✓
        Lone pairs repel more than bonded pairs ✓
        ALLOW ‘bonds’ for ‘bonded pairs’
        DO NOT ALLOW ‘atoms repel’
        DO NOT ALLOW electrons repel
        ALLOW LP for ‘lone pair’
        ALLOW BP for bonded pair

7. (i) 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^6\) ✓
   ALLOW subscripts

   [5]
(ii) ‘Dot-and-cross’ diagram to show four shared pairs of electrons one of which is a dative covalent bond (which must consist of the same symbols)

*IGNORE inner shells*

*IGNORE ‘+’ sign BUT DO NOT ALLOW a ‘−’ sign.*

*Brackets and circles not required*

1

(iii) tetrahedral

109.5°

*ALLOW 109 – 110°*

2

(iv) ions OR electrons cannot move in a solid

*ions can move OR are mobile in solution*

*ALLOW ions can move in liquid*

*DO NOT ALLOW ions can move when molten*

*ALLOW 1 mark for:*

‘Ions can only move in solution’

2

[6]
regular arrangement of labelled + ions with some attempt to show electrons ✓

scattering of labelled electrons between other species

OR

a statement anywhere of delocalised electrons (can be in text below) ✓

metallic bond as (electrostatic) attraction between the electrons and the positive ions ✓

Lattice must have at least 2 rows of positive ions

If a metal ion is shown (e.g. Na\(^+\)), it must have the correct charge

ALLOW for labels: + ions, positive ions, cations

If ‘+’ is unlabelled in diagram, award the label for ‘+’ from a statement of ‘positive ions’ in text below

DO NOT ALLOW as label or text positive atom OR protons

OR nuclei

ALLOW e\(^-\) OR e as label for electron

DO NOT ALLOW ‘–’ as label for electron

9. (i) 4 Na + O\(_2\) → 2 Na\(_2\)O

OR 2 Na + \(\frac{1}{2}\) O\(_2\) → Na\(_2\)O ✓

ALLOW correct multiples including fractions

IGNORE state symbols

(ii) (electrostatic) attraction between oppositely charged ions ✓
Na shown with either 8 or 0 electrons
AND
O shown with 8 electrons with 6 crosses and 2 dots (or vice versa)
Correct charges on both ions

For 1st mark, if 8 electrons shown around cation then ‘extra’ electron(s) around anion must match symbol chosen for electrons in cation
Shell circles not required
IGNORE inner shell electrons
ALLOW: 2[Na⁺] 2[Na⁺][Na⁺]₂ (brackets not required)
DO NOT ALLOW: [Na₂]²⁺ [Na₂]⁺ [2Na]²⁺ [Na]⁺

10. sodium is a (good) conductor because it has mobile electrons OR delocalised electrons
OR electrons can move
sodium oxide does not conduct as a solid
sodium oxide conducts when it is a liquid
ions cannot move in a solid
ions can move OR are mobile when liquid
Throughout this question, ‘conducts’ and ‘carries charge’ are treated as equivalent terms.
DO NOT ALLOW ‘free electrons’ for mobile electrons
ALLOW poor conductor OR bad conductor
‘Sodium oxide only conducts when liquid’ is insufficient to award ‘solid conductivity’ mark
ALLOW ions are fixed in place
IGNORE electrons
IGNORE charge carriers
IGNORE ‘delocalised ions’ or ‘free ions’ for mobile ions
Any mention of electrons moving is a CON

11. (i)
Hydrogen bond

\[ \delta^+ H - \cdots - O^- \delta^- H \delta^+ H - \cdots - O^- \delta^- H \]

Shape of water with at least one H with \( \delta^+ \) and at least one O with \( \delta^- \) ✔

H-bond between H in one water molecule and a lone pair of an O in another water molecule ✔

hydrogen bond labelled
OR \( H_2O \) has hydrogen bonding ✔

all marks can be awarded from a labelled diagram

If \( HO_2 \) shown then DO NOT ALLOW 1st mark
Dipole could be described in words so it does not need to be part of diagram.

At least one hydrogen bond must clearly hit a lone pair
Lone pair interaction could be described in words so it does not need to be part of diagram.

DO NOT ALLOW hydrogen bonding if described in context of intramolecular bonding, ie

\[ H - \cdots - O - H \]

(ii) no hydrogen bonding
OR weaker intermolecular forces ✔

DO NOT ALLOW 'weaker' / 'weak' hydrogen bonding
ALLOW weaker van der Waals' forces
ALLOW weaker dipole-dipole interactions
DO NOT ALLOW 'weak intermolecular forces'
(ie comparison essential here)
DO NOT ALLOW 'no intermolecular forces'
12. (i) positive ions (1) electrons (1) (must be labelled) 2
(ii) the electrons move (1) 1

13. (i) attraction between oppositely charged ions 1
(ii) Mg and Cl both with 8 electrons in outer shell, (accept 0 electrons for Mg) Cl must have one dot to seven crosses or vice versa (1) correct charges on each ion (1) 2
(iii) MgCl\(_2\) does not conduct when solid because ions are fixed in lattice (1) H\(_2\)O does not conduct as there are no free charge carriers/water molecules are uncharged (1) MgCl\(_2\) conducts when aqueous because ions are free to move (1) 3

14. To boil C\(_2\), van der Waals’ forces/intermolecular forces are broken (with van der Waals/intermolecular spelt correctly) (1)
To boil C, covalent bonds are broken (1) covalent bonds are stronger than van der Waals’ forces (1) [3]

15. (i) H\(_2\)O NH\(_3\) 2 3 (1)
2 1 (1) 2
16. H bonding from lone pair on O of 1 H₂O molecule to H of another (1) dipoles shown (1)

Two properties:
Ice is lighter than water/ max density at 4°C (1)

explanation: H bonds hold H₂O molecules apart
  / open lattice in ice
  / H-bonds are longer (1)

Higher melting/boiling point than expected (1)

explanation: strength of H bonds that need to be broken (1)

must imply that intermolecular bonds are broken

High surface tension/viscosity (1)

explanation: strength of H bonds across surface (1)

17. (i) 1s²2s²2p⁶3s²3p⁶ ✓
(ii) 3 ✓
(iii) 10 ✓
(iv) ‘dot-and-cross’ of Ca²⁺ with either 8 electrons or no electrons. ✓

‘dot-and-cross’ of 2OH⁻ correct ✓

N.B. H electron and Ca electrons can look the same.

Lattice must have at least two rows of positive ions. If a Mg ion is shown it must correct charge

ALLOW for labels: + ions, positive ions, cations

DO NOT ALLOW as label nuclei OR protons for positive ions

ALLOW e⁻ or e as label for electron

DO NOT ALLOW ‘–’ without label for electron

Cl has a simple molecular OR simple covalent (lattice) ✓✓ 18. (i)

attraction between oppositely charges ions ✓ 1
(ii) shared pair of electrons ✓✓
   ‘shared electrons’ scores 1 mark only

19. (i) attraction of an atom/element for electrons ✓
in a (covalent) bond/bonded pair ✓
(ii) one element attracts bonded pair more
    /is more electronegative than other ✓
    → δ– on more electronegative atom and δ+ on less
    electronegative element in example ✓
    
   May need to look for these marks below if not given here.

20. H–bond shown between H of one molecule and O, N or F of
    another ✓
    H-bond shown going to a lone pair ✓

21. (a) 3

<table>
<thead>
<tr>
<th>element</th>
<th>structure</th>
<th>bonding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg</td>
<td>giant</td>
<td>metallic</td>
</tr>
<tr>
<td>Si</td>
<td>giant</td>
<td>covalent</td>
</tr>
<tr>
<td>S</td>
<td>simple</td>
<td>covalent</td>
</tr>
</tbody>
</table>

1 mark for each correct row

(b) Si has strong forces between atoms/
    covalent bonds are broken ✓
    P has weak forces between molecules/
    intermolecular forces/van der Waals’ forces are broken ✓
(c) From Na → Al, no of delocalised electrons increases ✓
charge on positive ion increases/
ionic size decreases/
charge density increases ✓
attraction between + ions and electrons increases/
metallic bonding gets stronger ✓

22. (i) \( 2Na(s) + Cl_2(g) → 2NaCl(s) \) ✓✓
1st mark for equation 2
2nd mark for state symbols 2
(ii) Giant ionic (lattice) or 3D ✓
with alternating Na\(^{+}\) and Cl\(^{-}\) ✓ 2

23. 

Also accept Na with full shell as long as it contains ‘x’ s
(as in example above)
Ignore any inner shells
Correct dot and cross ✓
Correct charges ✓

24. (i) \( 2Na + O_2 → Na_2O_2 \) ✓ 1
(ii) \( Na_2O_2 + 2H_2O → H_2O_2 + 2NaOH \) ✓
correct covalent bonds shown ✓ 1
(iii) electron count (14) for rest of molecule correct ✓ 2
25. (i) (trigonal) pyramidal ✓

(ii) electron pairs repel/bonds repel
/electron pairs get as far apart as possible ✓
/lone pairs repel more/forces ‘them’ closer ✓

4 electron pairs surround central atom or N
/diagram with 3 bonds and a lone pair ✓

[4]

26. Original solution contains ions/there are mobile ions ✓
Charge carriers removed as reaction takes place
/as solid forms/ as BaSO₄ forms/as water forms ✓

[2]

27. general
NaCl: ionic/has ionic bonds ✓
 Beware of contradictions for this mark, especially reference to intermolecular forces.
 Ignore ‘atoms’.

graphite: covalent/giant molecular/macromolecular ✓
 Ignore van der Waals’, intermolecular, molecules

-------------------------------------------
conductivity

NaCl: ions cannot move/
no free ions (or electrons) /
mobile ions only in solution or when molten ✓

graphite:
delocalised electrons/
free electrons (between layers)/
electrons conduct ✓

Ignore lone pair

melting point

both graphite and NaCl:
bonds are strong/
bonds difficult to break /
large amount of energy is needed to break bonds ✓

solubility

NaCl: Water is polar/water has a dipole/
ions interacts with water molecules ✓

Graphite: no interaction with water/
no intermolecular forces with water/ 2
graphite is non-polar ✓

QWC: At least 2 complete sentences in which
the meaning is clear. ✓

28. (i)

positive ions ✓
electrons ✓ (must be labelled)
If Mg$^{2+}$ shown then must be correct: Mg$^+$ not worthy 2

(ii) electrons move ✓

[8]
29. (i) Oxidation state goes from 0 in O$_2$ → –2 in MgO

(ii) 
\[
\begin{array}{c}
\text{Mg} \\
2^+ \\
\end{array}
\begin{array}{c}
\text{O} \\
2^- \\
\end{array}
\]

or with Mg full shell.
correct dot and cross; correct charges

2

30. (i) mark vertically:

\[
\begin{array}{c|c|c}
\text{H}_2\text{O} & \text{NH}_3 \\
2 & 3 \\
2 & 1 \\
\end{array}
\]

3D Diagram required or diagram with name

(ii) labelled bond angle required

NH$_3$ pyramidal molecule shown 107° (106-108°)
SO$_2$ non-linear molecule shown 110 – 130°

2

31. (i) oxygen/ nitrogen is more electronegative/molecule has atoms with different electronegativities/oxygen/more electronegative atom … attracts bonded electron pair more

(ii) H bonding from N of 1 NH$_3$ molecule to H of another NH$_3$ molecule with a H$^+$ shown and a N$^-$ shown with lone pair involved in bond

2nd mark is available from water molecule(s)

2

32. ice is less dense than water

hydrogen bonds hold H$_2$O molecules apart in ice /
hydrogen bonds cause an open lattice structure

2
33. (i) \(107^\circ\) ✓ (accept any angle in the range \(108^\circ \rightarrow 91^\circ\)) 1
(ii) electron pairs repel electron pairs/bonds go as far apart as possible ✓
lone pairs repel more ✓ 2 [3]

34. attraction between oppositely charged ions/
oppositely charged atoms ✓ 1

For CaO: correct dot and cross ✓; correct charges ✓
For CO\(_2\): correct dot and cross ✓ 3 [5]

35. (i) dative covalent, bonded pair comes from same atom/
electron pair is donated from one atom/
both electrons are from the same atom ✓ 1
(ii) \(\text{Ca(NO}_3\text{)}_2 \rightarrow \text{CaO} + 2\text{NO}_2 + \frac{1}{2}\text{O}_2\) ✓
or double equation with 2/2/4/1 1 [2]

36. High boiling point or difficult to break linked to strong bonds in the right context within Li or C ✓ 1
Li conducts by delocalised/free/mobile electrons ✓ structure: giant ✓ metallic ✓ 3
or ‘+ ions with a sea of electrons’ for giant mark
C conducts by delocalised/free/mobile electrons ✓ structure: giant ✓ covalent
with layers ✓ 4
N No mobile charge carriers/electrons/ions to conduct electricity ✓
simple molecular structure/made of N\(_2\) molecules ✓
low boiling point or easily broken due to 3
intermolecular forces /
van der Waals’ forces ✓
QWC: At least 2 complete sentences in which the meaning is clear. ✓ 1 [12]

37. \(\text{CO}_2\): correct covalent bonds around carbon ✓
outer shell electrons correct ✓
(must be ‘dot AND cross’ or electron source clearly shown
(different coloured for source?)

38. correct dot and crosses ✓
correct charges ✓

39. uneven distribution of electrons ✓
instantaneous / oscillating / changing / temporary / transient /
dipole on one atom ✓
causes an induced / resultant dipole on another
molecule / atom ✓
chlorine gas; bromine liquid; iodine solid /
volatility decreases from Cl₂ → Br₂ → I₂ /
boiling point increases from Cl₂ → Br₂ → I₂ /
stronger forces are broken from Cl₂ → Br₂ → I₂ ✓
number of electrons increases down group ✓
greater / more van der Waals’ forces / induced dipole-
dipole interactions / forces between the molecules ✓

40. (i)

\[
\begin{array}{c}
\text{positive ions ✓} \\
\text{electrons ✓} \\
\text{(must be labelled)}
\end{array}
\]

(ii) electrons move ✓

41. simple molecular ✓
42. (i) \[ \text{Cl}_2 + 2\text{I}^- \rightarrow \text{I}_2 + 2\text{Cl}^- \]
   1 mark for species.
   1 mark for balancing
(ii) \( \text{Cl} \) atom is smaller/has less shells ✓
    electron to be captured will be attracted more ✓
   2

\[ \text{O43.} \]
(i) H bonding from O of 1 \( \text{H}_2\text{O} \) molecule to H of another ✓
   dipoles shown ✓ with lone pair involved in bond ✓
   3
(ii) Two properties from:
    Ice is lighter than water/ max density at 4°C ✓
    explanation: H bonds hold \( \text{H}_2\text{O} \) molecules apart
    / open lattice in ice
    / H-bonds are longer ✓
    Higher melting/boiling point than expected ✓
    explanation:
    strength of H bonds that need to be broken ✓
    must imply that intermolecular bonds are broken
    High surface tension/viscosity ✓
    explanation strength of H bonds across surface ✓
   4

44. \( \text{NH}_3 \): 107° ✓ (range 106 – 108°)
   electron pairs repel other electron pairs ✓
   lone pair has more repulsion ✓
   electron pairs get as far apart as possible ✓
   4

45. shared pair ✓ of electrons ✓
   i.e. 'shared electrons' is worth 1 mark. pair of electrons for second mark
   2
46. H₂O: all correct including lone pairs around O ✓
   CO₂: correct covalent bonds around carbon ✓
   lone pairs added around oxygen atoms ✓
   (must be ‘dot AND cross’ or electron source clearly shown
   (different coloured for source is OK)

47. (i) molecule shown as non-linear ✓
    angle: 104 - 105° ✓
    molecule shown as linear ✓

(ii) angle: 180° ✓

shape of H₂O
shape of CO₂
Electron pairs repel/groups (or regions) of electrons
repel/electron pairs get as far apart as possible ✓
Oxygen in water surrounded by 4 areas of electron
density/2 bonds and 2 lone pairs
AND
Carbon in CO₂ surrounded by 2 regions of electron
density/2 double bonds ✓

48. (i) Attraction of electrons ✓ in a bond ✓ towards an atom
    (ii) CO₂ is symmetrical/H₂O is not symmetrical ✓
        In CO₂, dipoles cancel/in H₂O, the dipoles don’t cancel ✓

49. (i)

+ + +
+ +
+ +
+ +

positive ions/cations ✓ and negative electrons ✓
Can be described in words only for both marks

(ii) contain free/mobile/delocalised electrons ✓

50. (i) shared pair of ✓ electrons ✓
i.e. ‘shared electrons’ is worth 1 mark. Pair of electrons for second mark

(ii) correct dot-and cross diagram ✓ 1

51. (i) electrostatic attraction ✓
   between oppositely charged ions ✓ 2
   (charged or electrostatic for 1st mark)
(ii) correct dot-and cross diagram ✓
correct charges ✓ 2
(iii) \[ \text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^- \]
\[ \text{F}_2 + 2\text{e}^- \rightarrow 2\text{F}^- \]
–sign not required with electron 2
(iv) solid: ions cannot move /in fixed positions in lattice ✓
solution: ions are free to move ✓ 2

52. \( \text{H}_2\text{O} \)
   H bonding from O of 1 molecule to H of another ✓
dipoles shown or described ✓ 3
   with lone pair of O involved in the bond ✓
   \( \text{CH}_4 \)
   van der Waals’ forces from oscillating dipoles/ temporary
dipoles/ transient dipoles/ instantaneous dipoles ✓
   leading to induced dipoles ✓
cauised by uneven distribution of electrons ✓ 3
53. Two properties from:
   Ice is less dense/lighter than water/floats on water/ max density at 4°C ✓

   explanation:  H bonds hold H₂O molecules apart
                 / open lattice in ice
                 / H-bonds are longer ✓  2

   Higher melting/boiling point than expected ✓

      Not just high
      Accept: ‘unusually high/strangely high/relatively high’

   explanation: H bonds need to be broken ✓  2

   High surface tension ✓

   explanation: strength of H bonds across surface ✓

   mark 2 properties only → 4 max

QoWC over whole question 1

   – legible text with accurate spelling, punctuation
     and grammar ✓  [5]