1 Which molecule has the largest dipole?

A ClF_3 ⬭

B BF_3 ⬭

C SF_6 ⬭

D CF_4 ⬭

(Total 1 mark)

2 Which of these atoms has the highest electronegativity?

A Na ⬭

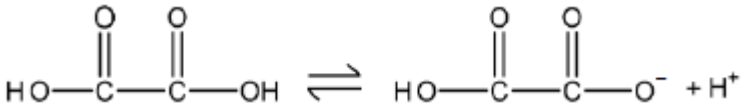
B Mg ⬭

C Cl ⬭

D Ar ⬭

(Total 1 mark)

3 Ethanedioic acid is a weak acid.
Ethanedioic acid acts, initially, as a monoprotic acid.



(a) Use the concept of electronegativity to justify why the acid strengths of ethanedioic acid and ethanoic acid are different.

.....

.....

.....

.....

.....

.....

.....

.....

(6)

(b) A buffer solution is made by adding 6.00×10^{-2} mol of sodium hydroxide to a solution containing 1.00×10^{-1} mol of ethanedioic acid ($H_2C_2O_4$).
Assume that the sodium hydroxide reacts as shown in the following equation and that in this buffer solution, the ethanedioic acid behaves as a monoprotic acid.

$$H_2C_2O_4(aq) + OH^-(aq) \longrightarrow HC_2O_4^-(aq) + H_2O(l)$$

The dissociation constant K_a for ethanedioic acid is 5.89×10^{-2} mol dm^{-3}.

Calculate a value for the pH of the buffer solution.
Give your answer to the appropriate number of significant figures.

pH = ...

(5)

(c) In a titration, the end point was reached when 25.0 cm^3 of an acidified solution containing ethanedioic acid reacted with 20.20 cm^3 of 2.00 $\times 10^{-2}$ mol dm^{-3} potassium manganate(VII) solution.

Deduce an equation for the reaction that occurs and use it to calculate the original concentration of the ethanedioic acid solution.

Equation .....

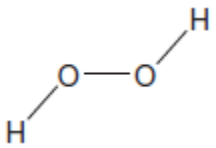
Calculation

Original concentration = ... mol dm^{-3}

(4)

(Total 15 marks)

4 A hydrogen peroxide molecule can be represented by the structure shown.



(a) Suggest a value for the H−O−O bond angle.

.....

(1)

(b) Hydrogen peroxide dissolves in water.

(i) State the strongest type of interaction that occurs between molecules of hydrogen peroxide and water.

.....

(1)

(ii) Draw a diagram to show how one molecule of hydrogen peroxide interacts with one molecule of water.
Include all lone pairs and partial charges in your diagram.

(3)

(c) Explain, in terms of electronegativity, why the boiling point of H_2S_2 is lower than H_2O_2.

.....

.....

.....

.....

.....

(2)
(Total 7 marks)

5 (a) Ammonia gas readily condenses to form a liquid when cooled.

(i) Name the strongest attractive force between two ammonia molecules.

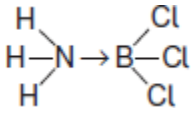
.....

(1)

(ii) Draw a diagram to show how two ammonia molecules interact with each other in the liquid phase.
Include all partial charges and all lone pairs of electrons in your diagram.

(3)

(b) Ammonia reacts with boron trichloride to form a molecule with the following structure.



State how the bond between ammonia and boron trichloride is formed.

.....

.....

.....

(1)

(c) The following table shows the electronegativity values of some elements.

	H	**Li**	**B**	**C**	**O**	**F**
Electronegativity	2.1	1.0	2.0	2.5	3.5	4.0

(i) Give the meaning of the term **electronegativity.**

.....

.....

.....

.....

(2)

(ii) Suggest the formula of an ionic compound that is formed by the chemical combination of two different elements from the table.

.....

(1)

(iii) Suggest the formula of the compound that has the least polar bond and is formed by chemical combination of two of the elements from the table.

.....

(1)

(Total 9 marks)

6 The following table shows the electronegativity values of the elements from lithium to fluorine.

	Li	Be	B	C	N	O	F
Electronegativity	1.0	1.5	2.0	2.5	3.0	3.5	4.0

(a) (i) State the meaning of the term *electronegativity*.

.....

.....

.....

(Extra space) .....

.....

(2)

(ii) Suggest why the electronegativity of the elements increases from lithium to fluorine.

.....

.....

.....

(Extra space) .....

.....

(2)

(b) State the type of bonding in lithium fluoride.
Explain why a lot of energy is needed to melt a sample of solid lithium fluoride.

Bonding .....

Explanation .....

.....

.....

(Extra space) .....

.....

(3)

(c) Deduce why the bonding in nitrogen oxide is covalent rather than ionic.

.....

.....

(Extra space) .....

.....

(1)

(d) Oxygen forms several different compounds with fluorine.

(i) Suggest the type of crystal shown by OF_2

.....

(1)

(ii) Write an equation to show how OF_2 reacts with steam to form oxygen and hydrogen fluoride.

.....

(1)

(iii) One of these compounds of oxygen and fluorine has a relative molecular mass of 70.0 and contains 54.3% by mass of fluorine.

Calculate the empirical formula and the molecular formula of this compound. Show your working.

Empirical formula .....

.....

.....

.....

.....

.....

Molecular formula .....

.....

(4)

(Total 14 marks)

7 The table below shows the electronegativity values of some elements.

	H	C	N	O
Electronegativity	2.1	2.5	3.0	3.5

(a) State the meaning of the term *electronegativity*.

.....

.....

.....

(2)

(b) State the strongest type of intermolecular force in the following compounds.

Methane (CH_4) .....

Ammonia (NH_3) .....

(2)

(c) Use the values in the table to explain how the strongest type of intermolecular force arises between two molecules of ammonia.

.....

.....

.....

.....

.....

(3)

(d) Phosphorus is in the same group of the Periodic Table as nitrogen.

A molecule of PH_3 reacts with an H^+ ion to form a PH_4^+ ion.

Name the type of bond formed when PH_3 reacts with H^+ and explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

(3)

(e) Arsenic is in the same group as nitrogen. It forms the compound AsH_3
Draw the shape of an AsH_3 molecule, including any lone pairs of electrons. Name the shape made by its atoms.

Shape

Name of shape .....

(2)

(f) The boiling point of AsH_3 is –62.5 °C and the boiling point of NH_3 is –33.0 °C.
Suggest why the boiling point of AsH_3 is lower than that of NH_3

.....

.....

.....

(1)

(g) Balance the following equation which shows how AsH_3 can be made.

..... $AsCl_3$ + ... $NaBH_4$ → ..... AsH_3 + ... NaCl + ... BCl_3

(1)
(Total 14 marks)

8 The table below shows the electronegativity values of some elements.

	Fluorine	Chlorine	Bromine	Iodine	Carbon	Hydrogen
Electronegativity	4.0	3.0	2.8	2.5	2.5	2.1

(a) Define the term *electronegativity*.

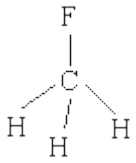
.....

.....

.....

(2)

(b) The table below shows the boiling points of fluorine, fluoromethane (CH_3F) and hydrogen fluoride.

	F–F		H–F
Boiling point/K	85	194	293

(i) Name the strongest type of intermolecular force present in:

Liquid F_2 .....

Liquid CH_3F .....

Liquid HF .....

(ii) Explain how the strongest type of intermolecular force in liquid HF arises.

.....

.....

.....

.....

(6)

(c) The table below shows the boiling points of some other hydrogen halides.

	HCl	HBr	HI
Boiling point / K	188	206	238

(i) Explain the trend in the boiling points of the hydrogen halides from HCl to HI.

.....

.....

.....

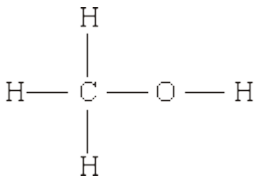
(ii) Give **one** reason why the boiling point of HF is higher than that of all the other hydrogen halides.

.....

.....

(3)
(Total 11 marks)

9 (a) Methanol has the structure



Explain why the O–H bond in a methanol molecule is polar.

.....

.....

.....

(2)

(b) The boiling point of methanol is +65 °C; the boiling point of oxygen is –183 °C. Methanol and oxygen each have an M_r value of 32. Explain, in terms of the intermolecular forces present in each case, why the boiling point of methanol is much higher than that of oxygen.

.....

.....

.....

.....

(3)
(Total 5 marks)

10 (a) Both HF and HCl are molecules having a polar covalent bond. Their boiling points are 293 K and 188 K respectively.

(i) State which property of the atoms involved causes a bond to be polar.

.....

.....

(ii) Explain, in terms of the intermolecular forces present in each compound, why HF has a higher boiling point than HCl.

.....

.....

.....

.....

.....

(4)

(b) When aluminium chloride reacts with chloride ions, as shown by the equation below, a co-ordinate bond is formed.

$$AlCl_3 + Cl^- \rightarrow AlCl_4^-$$

Explain how this co-ordinate bond is formed.

.....

.....

.....

(2)

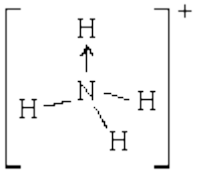
(c) Draw the shape of the PCl_5 molecule and of the PCl_4^+ ion. State the value(s) of the bond angles.

PCl_5 PCl_4^+

Bond angle(s) ..... *Bond angle(s)* .....

(4)
(Total 10 marks)

11 (a) An ammonium ion, made by the reaction between an ammonia molecule and a hydrogen ion, can be represented as shown in the diagram below.



(i) Name the type of bond represented in the diagram by N—H

.....

(ii) Name the type of bond represented in the diagram by N→H

.....

(iii) In terms of electrons, explain why an arrow is used to represent this N→H bond.

.....

.....

(iv) In terms of electron pairs, explain why the bond angles in the NH_4^+ ion are all 109° 28'

.....

.....

.....

.....

(7)

(b) Define the term *electronegativity*.

.....

.....

(2)

(c) A bond between nitrogen and hydrogen can be represented as $\overset{\delta-}{N}—\overset{\delta+}{H}$

(i) In this representation, what is the meaning of the symbol δ+ ?

.....

(ii) From this bond representation, what can be deduced about the electronegativity of hydrogen relative to that of nitrogen?

.....

.....

(2)

(Total 11 marks)

12 Which one of the following bond polarities is **not** correct?

A $\overset{\delta+}{C}-\overset{\delta-}{H}$ in ethane

B $\overset{\delta+}{C}-\overset{\delta-}{Br}$ in bromoethane

C $\overset{\delta+}{C}-\overset{\delta-}{O}$ in ethanol

D $\overset{\delta+}{C}=\overset{\delta-}{O}$ in ethanal

(Total 1 mark)

Mark schemes

1 A

[1]

2 C

[1]

3 (a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer is communicated coherently and shows a logical progression from stage 1 and stage 2 to stage 3. Steps in stage 3 must be complete, ordered and include a comparison.

Level 3
5 – 6 marks

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression from stage 1 and stage 2 to stage 3.

Level 2
3 – 4 marks

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

Level 1
1 – 2 marks

Insufficient correct Chemistry to warrant a mark.

Level 0
0 marks

Indicative Chemistry content

Stage 1: difference in structure of the two acids
- The acids are of the form RCOOH
- but in ethanoic acid R = CH_3
- whilst in ethanedioic acid R = COOH

Stage 2: the inductive effect
- The unionised COOH group contains two very electronegative oxygen atoms
- therefore has a negative inductive (electron withdrawing)effect
- The CH_3 group has a positive inductive (electron pushing) effect

Stage 3: how the polarity of OH affects acid strength
- The O–H bond in the ethanedioic acid is more polarised / H becomes more δ^+
- More dissociation into H^+ ions
- Ethanedioic acid is stronger than ethanoic acid

6

(b) Moles of NaOH = Moles of $HOOCCOO^-$ formed = 6.00×10^{-2}

Extended response

1

Moles of HOOCCOOH remaining = $1.00 \times 10^{-1} - 6.00 \times 10^{-2}$

$= 4.00 \times 10^{-2}$

1

$K_a = [H^+][A^-] / [HA]$

$[H^+] = K_a \times [HA] / [A^-]$

1

$[H^+] = 5.89 \times 10^{-2} \times (4.00 \times 10^{-2} / V) / (6.00 \times 10^{-2} / V) = 3.927 \times 10^{-2}$

1

$pH = -\log_{10}(3.927 \times 10^{-2}) = 1.406 = 1.41$

Answer must be given to this precision

1

(c) $5H_2C_2O_4 + 6H^+ + 2MnO_4^- \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

OR $5C_2O_4^{2-} + 16H^+ + 2MnO_4^- \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

1

Moles of $KMnO_4 = 20.2 \times 2.00 \times 10^{-2} / 1000 = 4.04 \times 10^{-4}$

1

Moles of $H_2C_2O_4 = 5 / 2 \times 4.04 \times 10^{-4} = 1.01 \times 10^{-3}$

1

Concentration = moles / volume (in dm^3)

$= 1.01 \times 10^{-3} \times 1000 / 25 = 4.04 \times 10^{-2}$ (mol dm^{-3})

If 1:1 ratio or incorrect ratio used, M2 and M4 can be scored

1

[15]

4 (a) 94−105.5°

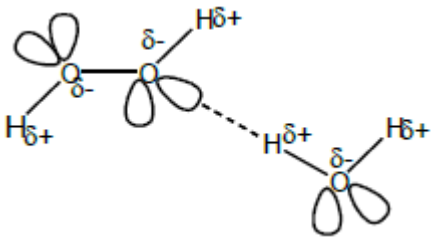
1

(b) (i) Hydrogen bond(ing) / H bonding / H bonds

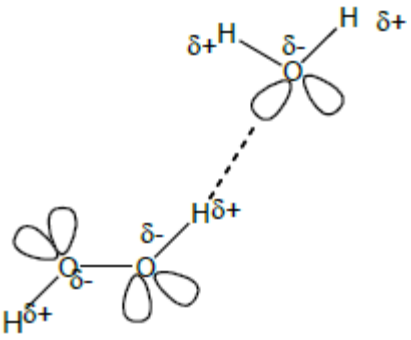
Not just hydrogen

1

(ii)



OR



1 mark for all lone pairs

1 mark for partial charges on the O and the H that are involved in H bonding

1 mark for the H-bond, from Hδ+ on one molecule to lone pair on O of other molecule

3

(c) Electronegativity of S lower than O or electronegativity difference between H and S is lower

Mark independently

1

No hydrogen bonding <u>between H_2S_2 molecules</u>

Or <u>only</u> van der Waals / <u>only</u> dipole-dipole forces <u>between H_2S_2 molecules</u>

If breaking covalent bonds CE = 0

1

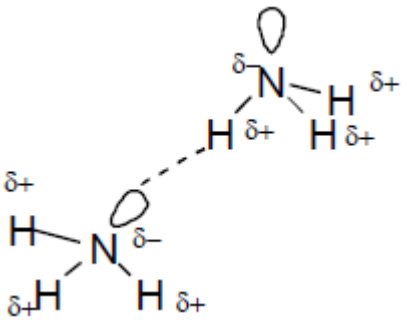
[7]

5 (a) (i) Hydrogen bonds / H bonds

Not just hydrogen.

1

(ii)



M1 – lone pair on each N.

M2 – correct partial charges must be shown on the N and H of a bond in each molecule.

M3 – for the H bond from lone pair on N to the Hδ⁺ on the other NH_3 molecule.

If not ammonia molecules, CE = 0 / 3.

3

(b) Lone pair / both electrons / 2 electrons / electron pair on N(H_3) is donated to B(Cl_3)

Allow both electrons in the bond come from N(H_3).

1

(c) (i) The power of an <u>atom</u> or <u>nucleus</u> to withdraw or attract electron<u>s</u> or electron density or a pair of electrons (towards itself)

1

in a <u>covalent</u> bond

1

(ii) LiF **OR** Li_2O **OR** LiH

Allow Li_2O_2, allow correct lithium carbide formula.

1

(iii) BH_3 / H_3B

Allow B_2H_6 / H_6B_2

Do not allow lower case letters.

1

[9]

6

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

Ignore retain

1

In a <u>covalent</u> bond

1

(ii) More protons / bigger nuclear charge

1

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

Not same sub–shell
Ignore more electrons

1

(b) Ionic

If not ionic then CE = 0 / 3
If blank lose M1 and mark on

1

Strong or many or lots of (electrostatic) attractions (between ions)

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

1

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

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

1

(c) Small electronegativity difference / difference = 0.5

Must be comparative
Allow 2 non-metals

1

(d) (i) (simple) molecular

Ignore simple covalent

1

(ii) $OF_2 + H_2O \longrightarrow O_2 + 2HF$

Ignore state symbols
Allow multiples
Allow OF_2 written as F_2O

1

(iii) 45.7% O

1

(O F)
(45.7 54.3)
(16 19)

If students get M2 upside down lose M2 + M3
Check that students who get correct answer divide by 16 and 19 (not 8 and 9). If dividing by 8 and 9 lose M2 and M3 but could allocate M4 ie max 2

1

(2.85 2.85)
(1 1)

EF = <u>OF or FO</u>

Calculation of OF by other correct method = 3 marks
Penalise Fl by 1 mark

1

MF (= 70.0 / 35) = O_2F_2 or F_2O_2

1

[14]

7 (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

1

From a <u>covalent bond</u> or from a shared pair of electrons;

Not distort
Not remove electrons

1

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

1

Hydrogen bonds/H bonds;

Not just hydrogen

1

(c) (Large) electronegativity difference between N + H/ difference of 0.9/ N very electronegative;

Insufficient to say N= 3.1 and H = 2.1

1

Forms N δ– / H δ+ or dipole explained in words;

Not N becomes (fully) negative or vice versa

1

<u>Lone pair on N</u> attracts/forms weak bonds with H (δ+);

QWC
Can score M2 and 3 from a diagram

1

(d) Co-ordinate/dative;

If not correct then CE = 0. If covalent/blank mark on.

1

Both electrons/ lone pair (on P/PH_3)

Not lone pair on hydrogen

1

Shares/donated from P(H_3)/ to H(δ+);

1

(e) 3 bonds and 1 lp attached to As;

Must label H and As atoms
Accept distorted tetrahedral not bent tetrahedral

1

Pyramidal/tetrahedral/ trigonal pyramidal;

Not bipyramidal/triangular

1

(f) (Only) weak Van der Waals forces between molecules /AsH_3 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 AsH_3 provided ammonia has stronger IMF.
If between atoms mentioned CE=0
Break bonds CE = 0

1

(g) $4AsCl_3 + 3NaBH_4 \rightarrow 4AsH_3 + 3NaCl + 3BCl_3$;

Accept multiples

1

[14]

8

(a) tendency / strength / ability / power of an atom / element / nucleus to attract / pull / withdraw electrons / e - density / bonding pair / shared pair

1

in a covalent bond

1

(b) (i) F_2 = van der Waals' / induced/temporary dipole-dipole / dispersion / London forces

1

CH_3F dipole-dipole

(not just 'dipole')

1

HF = hydrogen bonding

(not just 'H' / 'hydrogen')

1

(ii) large difference in electronegativity between H and F / F most/very/much more electronegative / values '4' & '2.1' quoted

(not just 'high <u>er</u>')

1

$^{\delta+}H\text{-}F^{\delta-}$ dipole created or dipole clearly implied

(accept arguments such as 'uneven charge in bond'/ 'polar bond' ∴ F slightly negative / H slightly positive)

1

attraction/bond formed between δ+H and lone pair on F

(M2 / M3 may be scored from a diagram)

(CE if full charges shown - lose M2 and M3)

1

(c) (i) van der Waals' / induced/temporary dipole-dipole / dispersion / London forces / attractions

(ignore references to dipole-dipole)

1

increase with the increasing M_r / size / mass / N^0 of e^- / size of e^- cloud (in the hydrogen halides)

(if ionic, or if 'covalent bonds broken' = CE = 0)

(mark M1 and M2 separately)

1

(ii) hydrogen bonding stronger than van der Waals' attraction/forces

(accept hydrogen bonding is very strong / strongest)

(accept arguments such as 'HF has H-bonds, others <u>only</u> have van der Waals')

(not just 'HF has H-bonding')

1

[11]

9

(a) Oxygen more/very/highly electronegative (than hydrogen)
OR oxygen has stronger attraction for <u>bonding</u> electrons / <u>bonding</u> electrons drawn towards oxygen;

1

causes higher e^- density round oxygen atom / causes $H^{\delta+}$ $O^{\delta-}$;

1

(b) van der Waals' forces between oxygen <u>molecules;</u>

1

Hydrogen bonding between methanol molecules;

1

H-B stronger than van der Waals' *OR* stronger IMF in methanol;

(if dipole-dipole forces in O_2 or methanol, allow comparison, hence max 2)

(if ionic/covalent etc. max 1)

(mention of bond break = CE = 0)

1

[5]

10

(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 **<u>intermolecular</u>** forces/attractions*

Note: if the explanation is <u>clearly</u> <u>intramolecular</u> = CE

4

(b) Electron <u>pair</u> **or** lone <u>pair</u> donated **(1)**

Do not accept 'donation of electrons'

From chloride ion to Al **or** $AlCl_3$ **(1)**

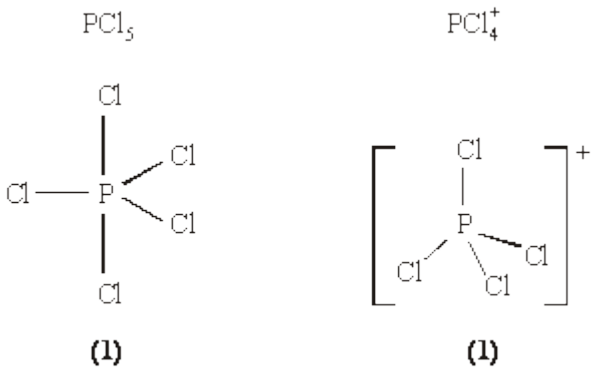
M1 can be earned by a general explanation of coordinate bonding, even if the electron pair is said to come from Al. The second mark, M2, is for this specific bond

Ignore missing charge

2

(c)

4



(1) (1)

PCl_5 shown as trigonal bipyramid PCl_4^+ 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)**

[10]

11 (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

as far apart as possible **(1)**

OR to position of minimum repulsion

tetrahedron **(1)**

7

(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.

2

(c) (i) Electron deficient **(1)**

Or small, slight, partial positive charge

(ii) H < N **(1)**

2

[11]

12 A

[1]