CAMBRIDGE INTERNATIONAL AS & A LEVEL CHEMISTRY · 9701

CHEMISTRY



MARK SCHEME

3 CHEMICAL BONDING

SCORE	PERCENTAGE
/	%

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Paper 1 Multiple Choice Answers: Chemical Bonding

Question	Paper	Q. No.	Answer
112	9701_w20_qp_11	5	B
113	9701_s21_qp_12	8	A
114	9701_s20_qp_11	3	B
115	9701_s19_qp_12	4	C
116	9701_m18_qp_12	6	D
117	9701_s18_qp_13	4	C
118	9701_s16_qp_11	2	B
119	9701_w16_qp_12	6	A
120	9701_s15_qp_11	10	A
121	9701_s15_qp_12	3	A
122	9701_m22_qp_12	25	D
123	9701_s21_qp_11	3	B
124	9701_s21_qp_13	4	A
125	9701_w21_qp_12	5	B
126	9701_m20_qp_12	3	A
127	9701_m20_qp_12	8	C
128	9701_s20_qp_13	2	A
129	9701_s20_qp_13	9	B
130	9701_m19_qp_12	4	C
131	9701_s19_qp_11	5	C
132	9701_w19_qp_11	3	D
133	9701_m18_qp_12	5	C
134	9701_s18_qp_12	18	C
135	9701_w18_qp_12	4	D
136	9701_w17_qp_11	3	D
137	9701_w17_qp_12	4	C
138	9701_m16_qp_12	6	C
139	9701_m16_qp_12	15	A
140	9701_s16_qp_11	5	C
141	9701_s16_qp_12	5	D
142	9701_s16_qp_13	7	C
143	9701_w16_qp_12	7	D
144	9701_s15_qp_13	4	C
145	9701_m22_qp_12	4	D
146	9701_m21_qp_12	5	C
147	9701_s21_qp_13	5	C
148	9701_w21_qp_11	5	C
149	9701_w21_qp_12	6	B
150	9701_w21_qp_12	7	D
151	9701_w21_qp_13	5	C
152	9701_s20_qp_12	8	C
153	9701_w20_qp_11	4	A
154	9701_s18_qp_11	5	D
155	9701_s17_qp_11	5	B
156	9701_s17_qp_12	4	D
157	9701_w17_qp_11	2	A

Paper 1 Multiple Choice Answers: Chemical Bonding (continued)

Question	Paper	Q. No.	Answer
158	9701_s16_qp_11	7	C
159	9701_s16_qp_13	6	A
160	9701_w16_qp_12	13	A
161	9701_s15_qp_11	2	D
162	9701_s15_qp_13	6	A
163	9701_w15_qp_11	4	A
164	9701_w15_qp_12	1	B
165	9701_m22_qp_12	5	B
166	9701_s21_qp_13	6	B

11. 9701_S15_ms_21 Q: 1

(a)

sub-atomic particle	relative mass	relative charge
neutron	**1**	0
electron	1/1836	**–1**
proton	**1**	**+1**

[1] [1] [1]

(b) (i)

RAM = mean / average mass of the isotopes / an atom(s) [1]
relative to 1/12 the mass of an atom of ^{12}C / on a scale where an atom of ^{12}C is (exactly) 12 (units) [1]

isotope = atoms with the same number of protons / atomic number / proton number with different mass numbers / numbers of neutrons / nucleon number [1]

(ii)

$$\frac{(0.89\times 74)+(9.37\times 76)+(7.63\times 77)+(23.77\times 78)+(49.61\times 80)+(8.73\times 82)}{100}$$ [1]

= 79.04 (2 d.p.) **AND** Se [1]

(c) (i)

Te	**C*l***	
$\frac{47.4}{128}$	$\frac{52.6}{35.5}$	[1]
$\frac{0.370}{0.370}$	$\frac{1.48}{0.370}$	
1	4	so EF = $TeCl_4$ [1]
		Empirical Formula Mass = 270 so MF = $TeCl_4$ [1]

(c) (ii)

Covalent **AND** simple / molecular [1]

low melting point / reaction with water [1]

(iii)

$TeCl_4 + 3H_2O \rightarrow H_2TeO_3 + 4HCl$
OR $TeCl_4 + 2H_2O \rightarrow TeO_2 + 4HCl$ [1]

(d) (i)

Yellow / orange flame [1]
White fumes / solid [1]
Yellow / green gas disappears [1]

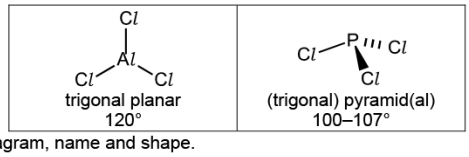
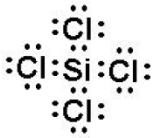
(ii)

NaCl giant / lattice **AND** ionic [1]
$SiCl_4$ simple / molecular **AND** covalent [1]

For NaCl large difference in electronegativity
(of sodium / Na and chlorine / Cl / Cl_2) (indicates electron transfer/ions) [1]

For $SiCl_4$ smaller difference (indicates sharing/covalency) with (weak) van der Waals' / IM forces (between molecules) ora [1]

12. 9701_w17_ms_22 Q: 1

(a)	 3 marking points for each box: diagram, name and shape. for each box: all three correct = 2 marks two correct = 1 mark	4
(b)(i)	$SiCl_4$ simple / molecular **AND** Van der Waals' / id-id forces / London / dispersion forces / IMFs	1
	NaCl ionic **OR** giant	1
	bonding (in NaCl) stronger (than forces in $SiCl_4$) owtte	1
(b)(ii)	$SiCl_4$ has more electrons ORA	1
	stronger Van der Waals' / id-id forces / London / dispersion forces / IMFs	1
(b)(iii)		1

13. 9701_s17_ms_21 Q: 2

(a)	<table><tr><td>substance</td><td>type of bonding</td><td>type of lattice structure</td></tr><tr><td>copper</td><td>metallic</td><td>giant/metallic</td></tr><tr><td>ice</td><td>covalent OR hydrogen(-bonding) / H(–bonding)</td><td>hydrogen-bonded / simple / molecular</td></tr><tr><td>silicon(IV) oxide</td><td>covalent</td><td>giant (molecular) / macromolecular</td></tr><tr><td>iodine</td><td>covalent</td><td>simple / molecular</td></tr><tr><td>sodium chloride</td><td>ionic</td><td>giant / ionic</td></tr></table>	1 1 1 1 1
(b)(i)	hydrogen bonding	1
(b)(ii)	H-bond between O and H of different molecules	1
	minimum **three** partial charges (in a row) over **two** H_2O molecules, i.e.: either $^{\delta-}O—H^{\delta+}$ - - - - $^{\delta-}O$ or $H^{\delta+}$ - - - - $^{\delta-}O—H^{\delta+}$	1
	lone pair of electrons on O of H-bond, in line with H-bond	1
(c)(i)	X = liquid AND Z = solid	1
	Y = liquid and solid OR 'liquid / solid' OR 'liquid OR solid'	1
(c)(ii)	(kinetic) energy reducing	1
	motion slowing *owtte*	1
(c)(iii)	energy given out / released forming bonds / forming bonds exothermic	1
	compensates for / counteracts heat loss / cooling *owtte*	1
	Total:	15

14. 9701_s16_ms_23 Q: 1

(a) (i)	$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$	[1]
(ii)	$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$	[1]
(iii)	$(0.025 \times 32.0/1000=)\ 8 \times 10^{-4}$	[1]
(iv)	$(8 \times 10^{-4} \times 6 =)\ 4.8 \times 10^{-3}$	[1]
(v)	$(4.8 \times 10^{-3} \times 250/25.0=)\ 4.8 \times 10^{-2}$	[1]
(vi)	$(4.8 \times 10^{-2} \times 55.8=)$ 2.68/2.678	[1]
(vii)	(2.68/3.35=) 80%	[1]
(b) (i)	covalent small(er) difference in electronegativity between Fe and C*l* (than between A*l* and C*l*)	[1] [1]
(ii)	$FeCl_3 + 6H_2O \rightarrow [Fe(H_2O)_6]^{3+}\ 3Cl^-$ OR $FeCl_3 + 6H_2O \rightarrow [Fe(H_2O)_6OH]^{2+} + H^+ + 3Cl^-$	[1]

15. 9701_S15_ms_23 Q: 1

(a)	$(1s^2)2s^22p^6$	[1]
(b) (i)	The amount of energy required/energy change when one electron is removed from each atom in one mol of gaseous atoms	[1] [1] [1]
(ii)	Greater nuclear charge/number of protons Same shielding/number of shells/energy level	[1] [1]
(c) (i)	mean/average mass of the isotopes/an atom(s) relative to 1/12 of the mass of an atom of ^{12}C/on a scale where an atom of ^{12}C is (exactly) 12	[1] [1]
(ii)	$20.2 = \frac{(20 \times 90.48) + (21 \times 0.27) + (9.25y)}{100}$ $\frac{2020 - 1815.27}{9.25} = 22.133$ y = 22	[1] [1]
(d) (i)	$pV = \frac{mRT}{M_r}$ $M_r = \frac{mRT}{pV} = \frac{0.275 \times 8.31 \times 298}{100 \times 10^3 \times 200 \times 10^{-6}}$ M_r = 34.05/34.1	 [1] [1]
(ii)	(Let % Ne = x so % Ar = 100-x) $\frac{20.2x + 39.9(100 - x)}{100} = 34.05$ % Ne = 29.7	 [1]
(e) (i)	Van der Waal's/London/dispersion Uneven electron distribution/temporary dipole Induced dipole-dipole attraction	[1] [1] [1]
(ii)	more electrons more polarisable/greater attraction/stronger IMFs	[1] [1]

16. 9701_w15_ms_22 Q: 1

(a)

name of isotope	type of particle	charge	symbol	electron configuration
carbon-13	atom	0	$^{13}_{6}C$	$1s^2 2s^2 2p^2$
chloride(-37)	anion	1−	Cl	$1s^2 2s^2 2p^6 3s^2 3p^6$
sulfur-34	atom	0	$^{34}_{16}S$	$1s^2 2s^2 2p^6 3s^2 3p^4$
iron-54	cation	2+	$^{54}_{26}Fe^{(2+)}$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

[5]

(b) (i) ability / tendency / power of an atom / nucleus to attract / pull electron(s) [1]

in a covalent bond / shared pair of electrons / bonding pair of electrons [1]

(ii) Covalent [1]
overlap of orbitals OR shared pair(s) (of electrons) [1]

OR
metallic [1]
positive ions / cations surrounded by delocalised electrons [1]

(iii) Ionic/electrovalent [1]
(electrostatic) Attraction between oppositely charged / +ve and –ve ions [1]

(c) (i) similar strength / amount / number of intermolecular forces / induced dipole / van der Waals' / VdW / London forces / LDF / dispersion forces [1]

therefore similar energy needed [1]

(ii) M1 HCl polar / has a dipole AND F_2 non-polar / has no dipole [1]
OR
(permanent) dipole (-dipole) attractions / forces between HCl (molecules) AND induced dipole (-induced dipole) attractions / forces / LDFs between F_2 (molecules)

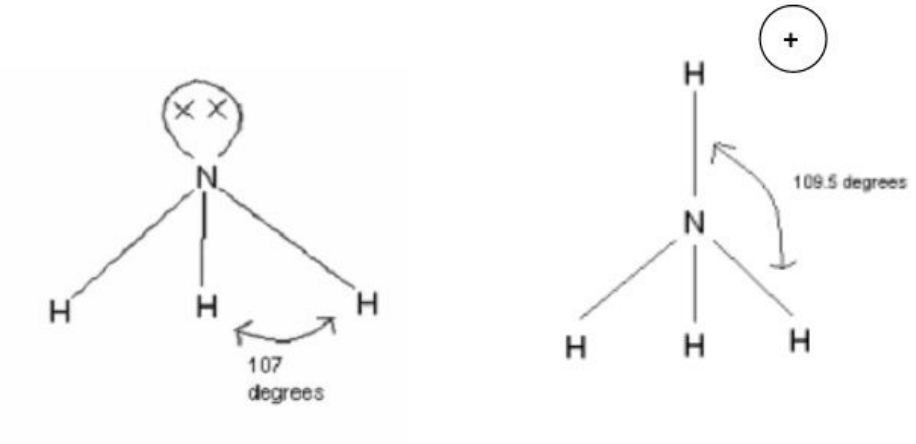
M2 more energy needed for HCl than F_2 [1]
OR
pd-pd forces stronger than id-id forces
OR
IMFs / VdWs in HCl stronger than in F_2

(iii) Hydrogen bonding (between methanol molecules) [1]

Stronger than IMFs / van der Waals' in other three / is the strongest intermolecular force [1]

Q1.

(d)

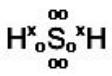


1 mark for each diagram, 1 mark for each correct bond angle
If not 3-dimensional diagram – 1 penalty.

[4]

Q2.

(c) (i)



(1)

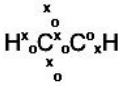
(ii) non-linear/bent/V-shaped (1)

(iii) H_2O has hydrogen bonds/H_2S does not <u>or</u>
H_2S has van der Waals' forces only (1)

hydrogen bonds are stronger
than van der Waals' forces <u>or</u>
H_2S has weaker intermolecular bonds
than H_2O (1) [4]

Q3.

2 (a)



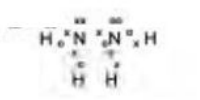
(1) [1]

Q4.

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1 **(a)** **(i)** between 117° and 120° [1]

(ii)



14 electrons must be shown
single N-N bond [1]
lone pair on each N atom [1]

(iii) between 107° and 109° [1] **[4]**

(b) ethene – van der Waals' forces [1]
hydrazine – hydrogen bonds [1]

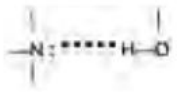
hydrogen bonds are stronger
or van der Waals' forces are weaker [1] **[3]**

(c) correct dipole on O—H and N—H bonds [1]

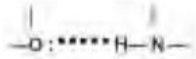
labelled hydrogen bond shown
between an O atom of H_2O and a H atom of N_2H_4
or between an N atom of N_2H_4 and a H atom of H_2O [1]

lone pair on O atom *or* on N atom *in the H bond*

i.e.



or



[1] **[3]**

(e) **(i)** acid – base/neutralization [1]

(ii) N atom has a lone pair of electrons
or N atom can behave as a base
or N atom can form dative bond [1]

(iii) each N atom has a lone pair
or each nitrogen atom can behave as a base
or each nitrogen atom can form a dative bond [1] **[3]**

Q5.

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1 **(a) (i)** 2 (1)

(ii) between 104° and 105° (1) [2]

(b)

ethanal	CH_3CHO	**A** (1)
ethanol	CH_3CH_2OH	**C** (1)
methoxymethane	CH_3OCH_3	**A** (1)
2-methylpropane	$(CH_3)_2CHCH_3$	**B** (1)

[4]

(c) (i) hydrogen bonds (1)

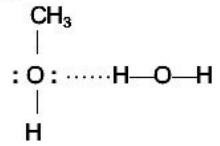
(c) (i) hydrogen bonds (1)

(ii) correct dipole on an -O—H bond (1)

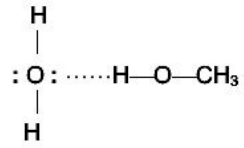
hydrogen bond shown between the lone pair of an O and a H atom in an –OH group (1)

lone pair on O atom of CH_3OH **or** H_2O clearly shown **in the hydrogen bond** (1)

e.g.



or



[4]

(d) hydrogen bonds exist between H_2O molecules (1)

hydrogen bonds cannot form between $C_2H_5OC_2H_5$ molecules (1) [2]

[Total: 12]

Q6.

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1 **(a)** A*l* $1s^2\ 2s^2 2p^6\ 3s^2 3p^1$ (1)

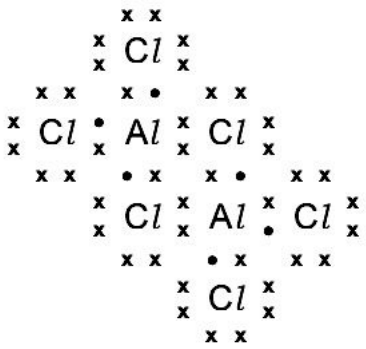
Ti $1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$ **or**

$1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 4s^2 3d^2$ penalise any error (1) [2]

(b) **(i)** pass chlorine gas (1)
over heated aluminium (1)

(ii) aluminium glows (1)
white/yellow solid formed (1)
chlorine colour disappears/fades (1) (any 2)

(iii)



correct numbers of electrons, i.e.

3 • per A*l* atom **and 7x** per C*l* atom

i.e. 6 • and 42 **x** in total (1)

dative bond C*l* to A*l* clearly shown by $^{x}_{x}$ (1) [6]

(c) chlorine is a strong/powerful oxidising agent (1) [1]

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(d) **(i)** $n(Ti) = \frac{0.72}{47.9} = 0.015$ (1)

(ii) $n(Cl) = \frac{(2.85 - 0.72)}{35.5} = 0.06$ (1)

(iii) 0.015 : 0.06 = 1:4
empirical formula of **A** is $TiCl_4$
Allow ecf on answers to **(i)** and/or **(ii)**. (1)

(iv) $Ti + 2Cl_2 \rightarrow TiCl_4$ (1)
Allow ecf on answers to **(iii)**. [4]

(e) covalent/not ionic (1)
simple molecular **or**
mention of weak intermolecular forces **or**
weak van der Waals's forces between molecules (1) [2]

[Total: 14 max]

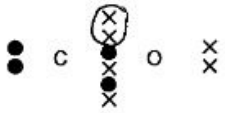
Q7.

1 **(a)** fewer electrons in Cl_2 than in Br_2 (1)
smaller van der Waals' forces in Cl_2 **or** stronger van der Waals' forces in Br_2 (1) [2]

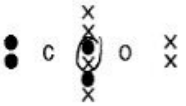
(b) CO has a permanent dipole **or** N_2 does not (1)
permanent dipole-permanent dipole interactions are stronger than those from induced dipoles (1) [2]

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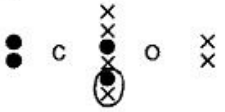
(c) **(i)** a co-ordinate bond (1)



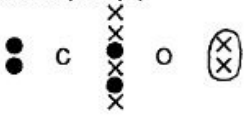
(ii) a covalent bond (1)



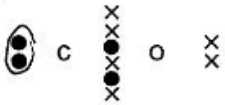
or



(iii) a lone pair (1)



or



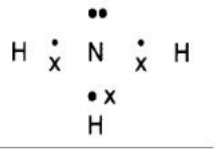
penalise any groups of 3 or 4 electrons that are circled [3]

(d) CO and HCN both have a dipole **or** N_2 does not have a dipole (1) [1]

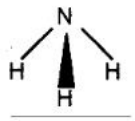
Q8.

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(c) (i) 'dot-and-cross' diagram (1)

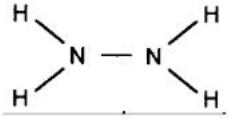


(ii)



(1)

(iii) minimum is



allow bond angle around N atom between 109° and 104° (1) **[4]**

(d) –2 (1) **[1]**

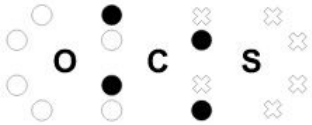
Q9.

(f) (i) both have very similar/same van der Waals' forces (1)

(ii) CH_3F has permanent dipole (1) [2]

Q10.

(f) (i)



(1)

(ii) 180° (1) [2]

Q11.

(c) (i) around the N atom there is only one lone pair
around the S atom there are two lone pairs **both** (1)

(ii) angle (a) **or** sulfur – **no mark for this**

because two lone pairs repel more than one lone pair **or**
lone pair-lone pair repulsions are stronger
than lone pair-bond pair repulsions (1) [2]

Q12.

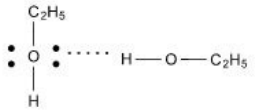
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(d) (i) hydrogen bonds (1)

(ii) lone pair on O atom of C_2H_5OH (1)

correct dipole $O^{\delta-}—H^{\delta+}$ on bond in one molecule of ethanol (1)

hydrogen bond shown between lone pair of an O atom and a hydrogen atom, i.e.



(1) [4]

Q13.

1 (a) (i)

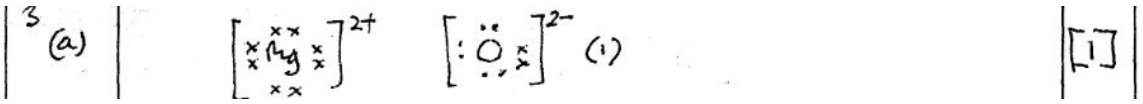


S atom has 6 **and C** atom has 4 electrons (1)

S=C double bonds (4 electrons) clearly shown (1)

(ii) linear **and** 180° (1) [3]

Q14.



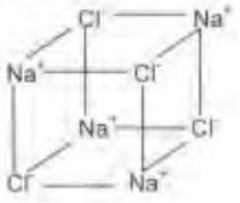
Q15.

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1 **(a)** ionic$^-$ (1)

Na^+ and Cl^- (1)

arranged in cubic lattice (diagram required)



(1)

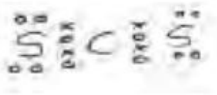
each na^+ ion surrounded by six Cl^- ions
or each Cl^- ion surrounded by six Na^+ ions
may be in diagram or stated in words (1) **[4]**

(b) in the solid, the ions cannot move (1)

in the melt, the ions move
or carry the charge/current (1) **[2]**

Q16.

(a)



sulphur atom has 6 /carbon atom has 4 electrons (1)

S=C double bonds (4 electrons) clearly shown (1) **[2]**

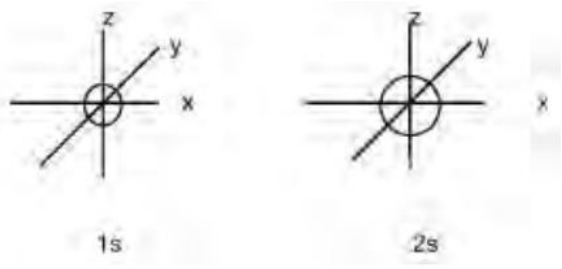
(b) linear (1)

180^o (1) **[2]**

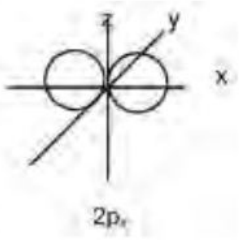
Q17.

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1 (a)



spherical (1) larger spherical (1)



double lobes along the *x*-axis (1) [3]

(b) (i) attraction between bonding electrons and nuclei (1)

attraction is electrostatic (1)

(ii) H_2 s-s **overlap** clearly shown

must **not** be normal dot/cross diagram (1)

H*Cl* s-p **overlap** clearly shown

overlap must involve s and p orbitals (1) [4]

(c) (i) bonding electrons are unequally shared **or**

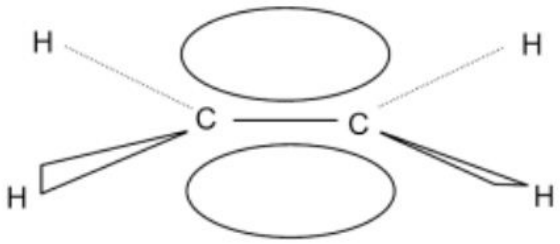
the molecule has a dipole/δ+ and δ- ends to molecule (1)

(ii) the H and C*l* atoms have different electronegativities

or chlorine is more electronegative than hydrogen (1) [2]

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(d)



allow two 'sausages' above **and** below the C-C axis

or two p orbitals **overlapping** sideways
to form one (localised) π bond over two carbon atoms (1) [1]

(e) $\Delta H_f^{\circ} = 2(-393.7) + 2(-285.9) - (-1411)$

$= +\ 51.8\ kJ\ mol^{-1}$ (units given in qu.) (3)

penalise errors: no 2 for –393.7
no 2 for –285.9
wrong sign for –(–1411) [3]

[Total: 13]

Q18.

(b) (i) giant ionic lattice (may be in diag.) (1)

strong ionic bonds (1)

(ii) simple molecular **or** discrete molecules

(may be shown in a diagram) (1)

with **weak** intermolecular forces **or**

weak van der Waals' forces

between them (1) [4]

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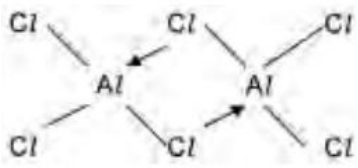
(e) (i) 460 K Al_2Cl_6 (1)

1150 K $AlCl_3$ (1)

(ii) correct **dot-and-cross** diagram for $AlCl_3$ (1)

(iii) correct displayed structure for Al_2Cl_6 (1)

two correct co-ordinate bonds (1)



[5]

Q19.

2 (a) (i) H–C–H 117 to 120° (1)
C=C=O 180° (1)

(ii) molecule contains **both** ketone **and** alkene (1) [3]

(b) (i) $C_2H_2O + 2O_2 \rightarrow 2CO_2 + H_2O$ (1)

(ii) from eqn., 42 g $C_2H_2O \rightarrow 48$ dm^3 of CO_2 (1)
whence 3.5 g $C_2H_2O \rightarrow \frac{48 \times 3.5}{42}$ dm^3 of CO_2 (1)
= 4.0 dm^3 of CO_2 (1)

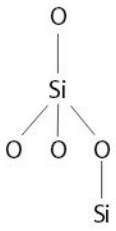
or $n(C_2H_2O) = \frac{42}{3.5} = 0.0833$ (1)
$n(CO_2) = 2 \times 0.083 = 0.0166$ (1)
vol. of $CO_2 = 0.0166 \times 24 = 4.0$ dm^3 (1)
allow e.c.f. on wrong eqn. in **(b)(i)**
penalise significant figure error [4]

Q20.

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1 **(a)** CO_2 is simple molecular/simple covalent/has discrete molecules (1)
CO_2 has induced dipole – induced dipole interactions/
van der Waals' forces/weak intermolecular forces (1)
SiO_2 is giant molecular/giant covalent/macromolecular (1)
SiO_2 has strong covalent bonds (1)
[any 3]

(b) minimum is 4-valent Si-O (1)
and at least one Si-O-Si (1)
i.e.



[2]

(c) **(i)** for an ideal gas, **any four** from the following
the molecules behave as rigid spheres (1)
there are no/negligible intermolecular forces
between the molecules (1)
collisions between the molecules are perfectly elastic (1)
the molecules have no/negligible volume (1)
the molecules move in random motion (1)
the molecules move in straight lines (1)
the kinetic energy of the molecules is
directly proportional to the temperature (1)
the pressure exerted by the gas is due to the collisions
between the gas molecules and the walls of the container (1)
not an ideal gas obeys $pV = nRT$
(max 4)

(ii) there are intermolecular forces between CO_2 molecules/
CO_2 molecules have volume (1) [5]

(d) graphite has delocalised electrons (1) [1]

(e) **(i)** $SiO_2 + 2C \rightarrow SiC + CO_2$ **or**
$SiO_2 + 3C \rightarrow SiC + 2CO$ (1)

(ii) diamond **because** SiC is hard (1) [2]

[Total: 13]

Q21.

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(b) (i) giant lattice (may be in diagram) (1)
with strong ionic bonding (1)

(ii) ionic (1)

(iii) –1 (1)

(iv)



correct numbers of electrons (1)
correct charges (1)

(v)

compound	MgH_2	AlH_3	PH_3	H_2S
oxidation number of element in the hydride	+2	+3	–3	–2

correct oxidation nos. for MgH_2 **and** AlH_3 (1)
correct oxidation nos. for PH_3 **and** H_2S (1) [8]

Q22.

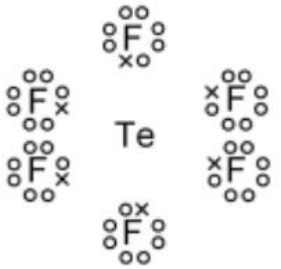
1 (a)

number of bond pairs	number of lone pairs	shape of molecule	formula of a molecule with this shape
3	0	trigonal planar	BH_3
4	0	tetrahedral	CH_4 allow other Group IV hydrides
3	1	pyramidal **or** trigonal pyramidal	NH_3 allow other Group V hydrides
2	2	non-linear **or** bent **or** V-shaped	H_2O allow other Group VI hydrides

1 mark for each correct row (3 × 1) [3]

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(b) (i)



(1)

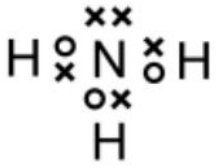
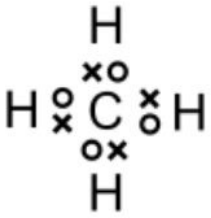
(ii) octahedral **or** square-based bipyramid (1)

(iii) 90° (1) [3]

[Total: 6]

Q23.

1 (a)

NH_3	CH_4
	
pyramidal	tetrahedral

both 'dot-and-cross' diagrams correct (1)
NH_3 is pyramidal **or** trigonal pyramidal (1)
CH_4 is tetrahedral (1) [3]

(b) (i) nitrogen and hydrogen have different electronegativities (1)
N–H bond has a dipole **or**
$N^{\delta-}—H^{\delta+}$ **or**
bonding pair is unequally shared (1)

(ii) molecule is not symmetrical **or**
dipoles do not cancel out (1)

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(iii) NH_3 has higher boiling point than expected from M_r value **or** has higher boiling point than methane
or NH_3 is soluble in water (1) [4]

(c) three covalent N–H bonds (1)
one co-ordinate (dative covalent) N–H bond (1)
one ionic bond between NH_4^+ and Cl^- (1) [3]

[Total: 10]

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