
CHEMISTRY

9701/21

Paper 2 AS Level Structured Questions

May/June 2017

MARK SCHEME

Maximum Mark: 60

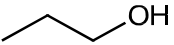
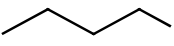
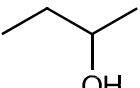
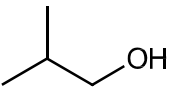
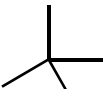
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Question	Answer	Marks
1(a)	The mass of a molecule OR the (weighted) average / (weighted) mean mass of the molecules	1
	Relative / compared to $\frac{1}{12}$ (the mass) of <u>an atom</u> of carbon-12 OR on a scale in which a carbon-12 atom / isotope has a mass of (exactly) 12 (units)	1
1(b)(i)	3	1
1(b)(ii)	8	1
1(b)(iii)	$\text{C}_3\text{H}_8\text{O} + 4\frac{1}{2}\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$	1
1(b)(iv)	 OH AND propan-2-ol / 2-propanol	1
	 AND propan-1-ol / 1-propanol	1
	Alternative answers (any two):	
	 OH AND butan-1-ol / 1-butanol  OH AND butan-2-ol / 2-butanol  AND (2-)methylpropan-1-ol / (2-)methyl-1-propanol  OH AND (2-)methylpropan-2-ol / (2-)methyl-2-propanol	

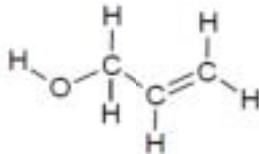
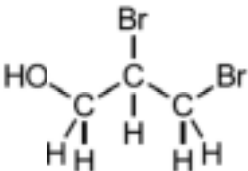
Question	Answer	Marks
1(b)(v)	correct conversions of data to SI/consistent units $p = 100\,000$; $V = 20 \times 10^{-6}$; $T = 393$	1
	calculation of $n (= pV/RT)$ from M1 values $n = \frac{100 \times 10^3 \times 20 \times 10^{-6}}{8.31 \times 393}$	1
	calculation of mass $m (= n \times Mr)$ AND answer correct to 3sf $m = 6.12 \times 10^{-4} \times 60 = 0.0367$ (g) Alternative answer for using $C_4H_{10}O$: $m = 6.12 \times 10^{-4} \times 74 = 0.0453$ (g)	1
	Total:	10

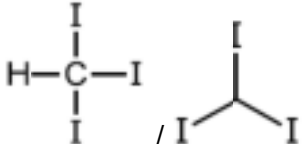
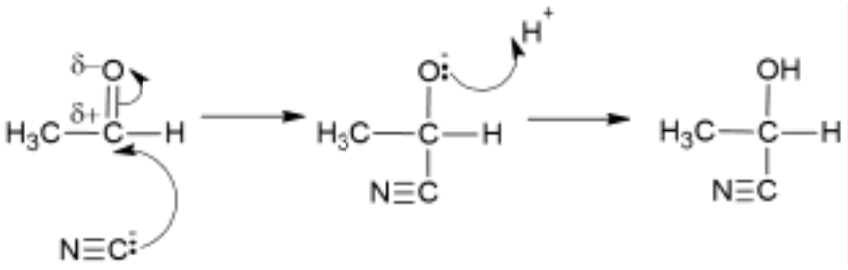
Question	Answer			Marks
2(a)	substance	type of bonding	type of lattice structure	1
	copper	metallic	giant/metallic	
	ice	covalent OR hydrogen(-bonding) / H(-bonding)	hydrogen-bonded / simple / molecular	1
	silicon(IV) oxide	covalent	giant (molecular) / macromolecular	1
	iodine	covalent	simple / molecular	1
	sodium chloride	ionic	giant / ionic	1
2(b)(i)	hydrogen bonding			1

Question	Answer	Marks
2(b)(ii)	H-bond between O and H of different molecules	1
	minimum three partial charges (in a row) over two H ₂ O molecules, i.e.: either $\delta^- \text{O} - \text{H}^{\delta+} \text{ --- } \delta^- \text{O}$ or $\text{H}^{\delta+} \text{ --- } \delta^- \text{O} - \text{H}^{\delta+}$	1
	lone pair of electrons on O of H-bond, in line with H-bond	1
2(c)(i)	X = liquid AND Z = solid	1
	Y = liquid and solid OR 'liquid / solid' OR 'liquid OR solid'	1
2(c)(ii)	(kinetic) energy reducing	1
	motion slowing <i>owtte</i>	1
2(c)(iii)	energy given out / released forming bonds / forming bonds exothermic	1
	compensates for / counteracts heat loss / cooling <i>owtte</i>	1
	Total:	15

Question	Answer	Marks
3(a)(i)	A	1
3(a)(ii)	H	1
3(a)(iii)	G	1
3(a)(iv)	B	1
3(a)(v)	F	1
3(b)(i)	(strong) heating	1
	(to provide / overcome) <u>high</u> activation energy	1
3(b)(ii)	<u>white</u> flame / <u>white</u> light / <u>white</u> smoke / <u>white</u> solid	1
3(b)(iii)	$\text{Mg(s)} + 2\text{H}_2\text{O(l)} \rightarrow \text{Mg(OH)}_2\text{(s)} + \text{H}_2\text{(g)}$	2
3(c)(i)	$2\text{Mg(NO}_3)_2 \rightarrow 2\text{MgO} + 4\text{NO}_2 + \text{O}_2$	1
3(c)(ii)	$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$	1
	$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$	1
3(d)(i)	reduce acidity in soil / increase pH of soil	1
	(both) basic / base(s)	1
3(d)(ii)	$\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{CO}_2 + \text{H}_2\text{O}$ OR $\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{H}_2\text{CO}_3$	1
	Total:	16

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Question	Answer	Marks
4(a)(i)	(molecules / isomers with) the same molecular formula / same number of atoms of each element	1
	different structural / displayed formulae / arrangement of bonds	1
4(a)(ii)	sp^2 overlap of (2)s with two (2)p (atomic) orbitals	1
	sp^3 overlap of (2)s with all three (2)p (atomic) orbitals	1
4(a)(iii)	$sp^2 = 116^\circ - 124^\circ$	1
	$sp^3 = 106^\circ - 112^\circ$	1
4(b)(i)		1
4(b)(ii)	(electrophilic) addition	1
	bromine decolourises / turns colourless / fades (from orange / brown)	1
4(b)(iii)	$HOCH_2CHBrCH_2Br$ OR 	1
4(b)(iv)	CO_2 / carbon dioxide	1
4(c)(i)	P = propanal	1
	Q = propanone	1

Question	Answer	Marks
4(c)(ii)	 tr(i)iodomethane / CHI_3 /	1
4(d)(i)	(molecules / isomers with) the same (molecular and) structural formula	1
	Any two of: chiral centre / C attached to four different groups / atoms non-super(im)posable mirror images different spatial / 3D arrangement of atoms (owtte) different rotation of plane-polarised light	1
4(d)(ii)		
	curly arrow from lone pair on $\text{:C}\equiv\text{N}$ to $\text{C}^{(\delta+)}$	1
	correct dipole on carbonyl $\delta^+\text{C}=\text{O}^{\delta-}$ AND curly arrow from bond to $\text{O}^{(\delta-)}$	1
	correct intermediate, including $\text{C}-\text{O}^-$ AND curly arrow from lone pair to H^+	1
	Total:	19

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Question	Answer						Marks
1(a)	atomic number	nucleon number	number of electrons	number of protons	number of neutrons	symbol	2 1 1
		6		3	3		
						$^{58}_{26}\text{Fe}^{3+}$	
1(b)(i)	EITHER mass of an atom / isotope relative / compared to 1/12 (the mass) of (an atom of) C-12 OR on a scale in which a C-12 (atom / isotope) has (a mass of exactly) 12 (units) OR mass of one mol (of atoms) of an isotope relative / compared to 1/12 (the mass) of 1 mol of C-12 OR on a scale in which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g						2 1 1
1(b)(ii)	$\frac{(10.0129 \times 19.78) + (80.22x)}{100} = 10.8$						1
	x = 10.9941						1
	Total:						6

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Question	Answer	Marks
2(a)	strong triple bond	1
	non-polar / no dipole	1
2(b)(i)	Any 2 points covered correctly scores 2 marks Any 1 point covered correctly scores 1 mark - nitrogen (and oxygen) from the air / atmosphere (react): - high temperature (of internal combustion engine) / (engine) produces enough OR a lot of heat (energy) : (so) breaks (strong) bond(s) in nitrogen (and oxygen) :	2
2(b)(ii)	reduction / decomposition of NO _x using a catalyst / catalytic convertor	1
	2NO ₂ + 4CO → 4CO ₂ + N ₂ OR 2NO + 2CO → 2CO ₂ + N ₂	1
2(b)(iii)	(acts as a homogeneous) catalyst OR oxidising agent	1
	SO ₂ + NO ₂ → SO ₃ + NO	1
	NO + ½O ₂ → NO ₂ OR SO ₃ + H ₂ O → H ₂ SO ₄	1
2(b)(iv)	2NO ₂ + H ₂ O → HNO ₂ + HNO ₃ OR 4NO ₂ + 2H ₂ O + O ₂ → 4HNO ₃	1
2(c)	fertiliser / nitrates dissolve in (river water) OR fertiliser / nitrates are washed / leached out / flows into (river water)	1

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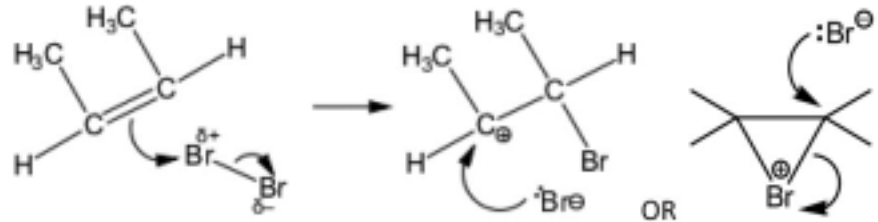
Question	Answer	Marks
	algal bloom / promote algal growth / explosion of plant growth AND EITHER sunlight is blocked out (preventing photosynthesis) / plants can no longer carry out photosynthesis (and die) OR bacteria break down or decay dead organisms / plants / algae	1
	drop in oxygen (concentration)	1
	Total:	13

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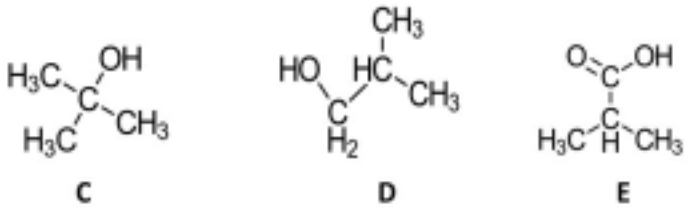
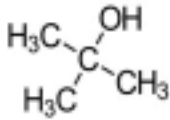
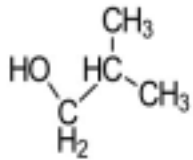
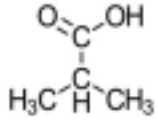
Question	Answer	Marks
3(a)	(+) 103	1
3(b)(i)	general shape of the curve and peak are displaced to right of original and starts at origin	1
	the peak is lower and curve crosses once only finishing above original	1
3(b)(ii)	rate increases AND correct explanation in terms of 'more collisions'	1
	at higher T area above E_a is greater / more molecules with $E \geq E_a$	1
	higher frequency of successful collisions OR more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time	1
3(b)(iii)	increases (%) decomposition (of HBr)	1
	(increasing T) shifts equilibrium to the right / in the forward direction / endothermic direction / towards $H_2 + Br_2$	1
	to oppose the change or oppose the increase in temperature OR to absorb (additional) energy / heat OR to decrease the temperature	1
3(b)(iv)	H-I bond strength less than H-Br OR less energy needed to break H-I <i>ora</i>	1
	I (atom) is big(ger) (than Br) OR I (atom) has more shielding (than Br) <i>ora</i>	1
	Br (atom) has greater (%) orbital / outer shell overlap OR attraction (of nucleus in iodine) for shared (pair of) electrons is weak(er) OR attraction (of nucleus in iodine) for bonding pair (or electrons) is weak(er) <i>ora</i>	1

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Question	Answer	Marks
3(c)(i)	$H_2 = 0.015 \text{ (mol)}$	1
	$HCl = 0.27 \text{ (mol)}$	1
3(c)(ii)	$HCl = 9/10$ AND $x_{H_2} = 1/20$ AND $C_{l_2} = 1/20$ OR $HCl = 0.9(0)$ AND $H_2 = 0.05$ AND $C_{l_2} = 0.05$	1
3(d)(i)	$(K_p =) \frac{p_{H_2} \times p_{Cl_2}}{p_{HCl}^2}$	1
3(d)(ii)	equal number of moles (of gas) on either side (of equation) / (total) pressure cancels	1
3(d)(iii)	4.649×10^{-3}	1
	Total:	18

Question	Answer	Marks
4(a)(i)	(A =) 	1
4(a)(ii)	(A / straight chain) has strong(er) (temporary dipole-) induced dipole (attractions) <i>ora</i>	1
	(because A / straight chain has) bigger (surface) area / more (points of) contact (in unbranched isomer) <i>ora</i> OR (so) more energy required to break the intermolecular forces <i>ora</i>	1
4(a)(iii)	CH ₃ CHCHCH ₃ OR CH ₃ CH=CHCH ₃	1
4(a)(iv)	No rotation / restricted / limited rotation of C=C / (carbon) double bond	1
	One (of the two) methyl groups / one (of the two) H (atoms) is on each C (of C=C)	1
4(a)(v)		1
	arrow from the C=C double bond drawn to the bromine	1
	dipole on Br ₂ in correct orientation AND arrow from the Br-Br bond to the Br ^{δ-}	1
	correct carbocation / bromonium ion from the structure with C=C drawn OR Br ⁻ with lone pair, negative charge AND arrow from lone pair to the carbon atom of intermediate OR using both arrows shown (in alternative diagram)	1
4(a)(vi)	electrons in pi bond induce it (the dipole) OR (high) electron density in pi bond / double bond / C=C repels electrons (away from nearest Br) OR polarised by (high) electron density in pi bond / double bond / C=C	1

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Question	Answer	Marks
4(b)(i)	C = (2-)methylpropan-2-ol / $(\text{CH}_3)_3\text{COH}$ / any unambiguous structure	1
	D = (2-)methylpropan-1-ol / $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$ / any unambiguous structure	1
	E = (2-)methylpropanoic acid / $(\text{CH}_3)_2\text{CHCO}_2\text{H}$ / any unambiguous structure	1
	   	
4(b)(ii)	$2\text{C}_4\text{H}_8\text{O}_2 + \text{Na}_2\text{CO}_3 \rightarrow 2\text{C}_4\text{H}_7\text{O}_2\text{Na} + \text{H}_2\text{O} + \text{CO}_2$	1
4(c)(i)	triiodomethane	1
4(c)(ii)	F = $\text{CH}_3\text{CH}_2\text{CH}_2\text{COCH}_3$	1
	G = $\text{C}_2\text{H}_5\text{CH}(\text{CH}_3)\text{CHO}$	1
4(c)(iii)	a (tetrahedral) atom with four different groups / atoms / substituents attached OR a carbon (atom) with four different groups / atoms / substituents attached	1
4(d)(i)	H $\text{C}=\text{O}$ (group / bond) AND $\text{O}-\text{H}$ (group / bond)	1
	I $\text{C}=\text{O}$ (group / bond) AND $\text{C}-\text{H}$ (group / bond)	1

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Question	Answer	Marks
4(d)(ii)	H = ethanoic acid	1
	I = methyl methanoate	1
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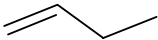
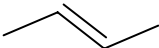
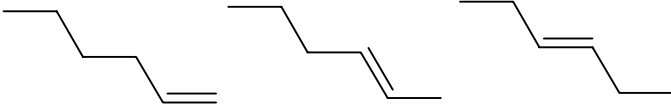
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Question	Answer	Marks
1(a)	(molecules / isomers with) the same molecular formula / same number of atoms of each element	1
	different structural / displayed formulae / different arrangement of bonds	1
1(b)(i)	4	1
1(b)(ii)	6	1
1(b)(iii)	molecular = C ₄ H ₈	1
	empirical = CH ₂ using alternative supplied data molecular = C ₆ H ₁₂ empirical = CH ₂	1

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Question	Answer	Marks
1(b)(iv)		1
		1
	alternative using supplied data: any two	
		
1(b)(v)	correct conversions of data to SI / consistent units $P = 100\,000$; $V = 25 \times 10^{-6}$; $T = 310$	1
	calculation of n ($= pV / RT$) $n = \frac{100 \times 10^3 \times 25 \times 10^{-6}}{8.31 \times 310}$	1
	calculation of mass m ($= n \times M_r$) AND answer correct to 3sf $m = 9.705 \times 10^{-4} \times 56 = 0.0543$ (g)	1
	Alternative answer for using C_6H_{12} : $m = 9.705 \times 10^{-4} \times 84 = 0.0815$ (g)	
	Total:	11

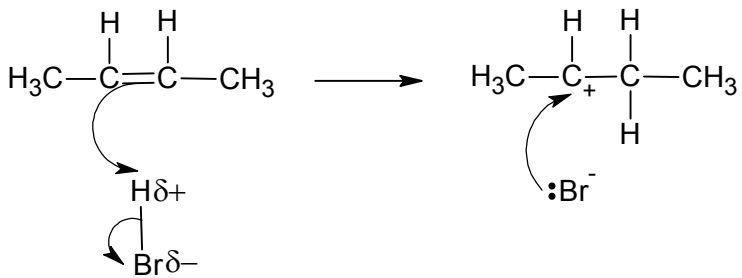
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Question	Answer			Marks
2(a)(i)	halogen	colour	state	2
	chlorine	yellow / green	gas	
	bromine	red / brown / orange	liquid	
	iodine	grey / black	solid	
2(a)(ii)	increasing number of electrons			1
	(gives) increasing strength of van der Waals' / id-id forces / London / dispersion forces			1
2(b)	oxidising power decreases down the group. <i>ora</i>			1
	ability to accept electrons decreases (down the group) <i>ora</i>			1
	because (outer shell experiences) more shielding OR increased distance from nucleus (to outer shell) (outweighs the increasing nuclear charge down the group) <i>ora</i>			1
2(c)(i)	solid sodium chloride: steamy / misty / white fumes			1
	solid sodium iodide: purple fumes			1
2(c)(ii)	(conc sulfuric) not powerful enough oxidising agent (to oxidise chloride) OR chloride not powerful enough reducing agent (to reduce sulfuric acid)			1
	iodide reduces sulfuric acid OR iodide / I ⁻ is oxidised OR sulfuric acid oxidises iodide			1

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Question	Answer	Marks
3(b)(ii)	2 marks for any two points: - Benefit of using a catalyst in terms of increasing rate or economic benefit i.e. (less heat required) - Creates alternative pathway with lower E_a - More molecules with $E > E_a$	2
3(b)(iii)	(rate) increases AND correct explanation in terms of 'more collisions'	1
	more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time	1
	(yield) increases and shifts equilibrium to the right / in the forward direction / towards SO_3 / towards the product / in exothermic direction	1
	to oppose the change or oppose the increase in pressure / fewer molecules on RHS so eqm moves to right (to oppose change)	1
3(c)(i)	$\text{SO}_2 = 0.01$ (mol) AND $\text{SO}_3 = 0.99$ (mol)	1
3(c)(ii)	$n_{\text{TOT}} = 1.505$	1
	$p_{\text{O}_2} = 1.50 \times 10^5 \times (0.505 / 1.505) = 5.03 \times 10^4$ (Pa)	1
3(d)(i)	$(K_p) = \frac{p_{\text{SO}_3}^2}{p_{\text{O}_2} \times p_{\text{SO}_2}^2}$	1
3(d)(ii)	0.1946737305	1
	Pa^{-1}	1
	Total:	17

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Question	Answer	Marks
4(a)	cracking	1
4(b)	In any order $\text{CH}_2=\text{CHCH}_2\text{CH}_3$ / $\text{CH}_2\text{CHCH}_2\text{CH}_3$ / $\text{CH}_2\text{CHC}_2\text{H}_5$ AND $\text{CH}_3\text{CH}=\text{CHCH}_3$ / $\text{CH}_3\text{CHCHCH}_3$ AND $(\text{CH}_3)_2\text{C}=\text{CH}_2$ / $(\text{CH}_3)_2\text{CCH}_2$	1
4(c)(i)	(different) molecules with the same (molecular and) structural formula	1
	(due to) different arrangement in space caused by $\text{C}=\text{C}$ / double bond	1
4(c)(ii)	 arrow from the $\text{C}=\text{C}$ double bond drawn to the H	1
	dipole on $\text{H}-\text{Br}$ in correct orientation AND arrow from the $\text{H}-\text{Br}$ bond to the $\text{Br}^{\delta-}$	1
	correct carbocation from the structure with $\text{C}=\text{C}$ drawn	1
	Br^- with lone pair, negative charge AND arrow from lone pair to the positively charged carbon atom of intermediate	1

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Question	Answer	Marks
4(d)(i)	a (tetrahedral) atom with four different groups / atoms / substituents attached OR a carbon (atom) with four different groups / atoms / substituents attached	1
4(d)(ii)	but-1-ene	1
4(d)(iii)	One 3D structure of 2-bromobutane which must have 2 bonds shown the same and two different, i.e. three bond types altogether, e.g. two solid lines, one wedge and one dash. If two bonds are drawn in the plane of the paper, i.e. single solid lines, they must not be at 180 degrees to each other.	1
	Second structure either mirror of first OR all bonds drawn the same with position of two groups swapped.	1
4(d)(iv)	intermediate / (secondary carbo) cation from X is more stable ora OR charge density of C ⁺ (of the intermediate of X) is reduced	1
	(due to) electron-releasing character / (positive) inductive effect of alkyl groups / / due to electron releasing alkyl group	1
4(e)(i)	(2-)methylpropene / (2-)methylprop-1-ene	1
4(e)(ii)		2
	Total:	17