



Cambridge International AS & A Level

CHEMISTRY

9701/21

Paper 2 AS Level Structured Questions

May/June 2023

MARK SCHEME

Maximum Mark: 60

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the May/June 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

PUBLISHED**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

PUBLISHED**GENERIC MARKING PRINCIPLE 5:**

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

Science-Specific Marking Principles

1	Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
2	The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.
3	Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).
4	The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.
5	<u>'List rule' guidance</u> For questions that require <i>n</i> responses (e.g. State two reasons ...): • The response should be read as continuous prose, even when numbered answer spaces are provided. • Any response marked <i>ignore</i> in the mark scheme should not count towards <i>n</i>. • Incorrect responses should not be awarded credit but will still count towards <i>n</i>. • Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should not be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response. • Non-contradictory responses after the first <i>n</i> responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.

For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.

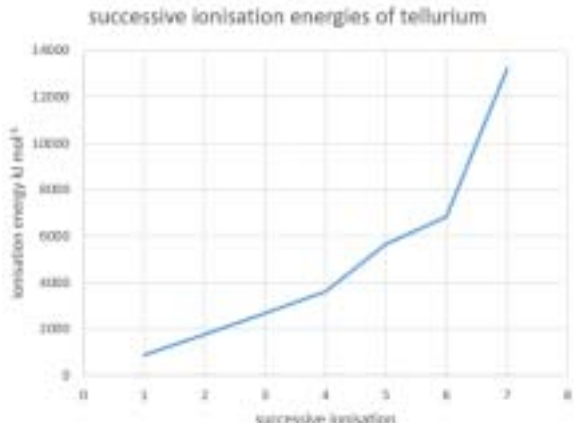
For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

7 Guidance for chemical equations

Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

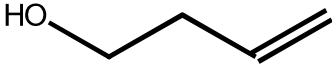
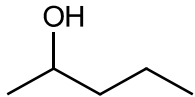
Question	Answer				Marks								
1(a)	<table><tr><td></td><td>nucleon number</td><td>number of neutrons</td><td>number of electrons</td></tr><tr><td>Tellurium-130</td><td>130</td><td>78</td><td>52</td></tr></table>					nucleon number	number of neutrons	number of electrons	Tellurium-130	130	78	52	3
	nucleon number	number of neutrons	number of electrons										
Tellurium-130	130	78	52										
1(b)	1 s				1								
1(c)	$\text{Te(g)} \rightarrow \text{Te}^{\text{+}}(\text{g}) + \text{e}^{(-)}$				1								
1(d)(i)	<i>any two factors responsible for increase in IE in first 6 IE from:</i> • (increased) nuclear attraction / attraction for nucleus • (decreased) shielding (by sub-shells) (IE 4 to 5) • spin-pair repulsion (IE 1 to 2)				2								
1(d)(ii)	successive ionisation energies of tellurium  M1 general increase M2 jumps from 4 to 5 and (largest) 6 to 7				2								
1(e)	M1 6 bonding pairs (of electrons and 0 lone pairs) OR coordination number = 6 OR x = 6 M2 bonding pairs repel (equally)				2								
1(f)(i)	$\text{TeF}_x + x\text{H}_2\text{O} \rightarrow \text{Te}(\text{OH})_x + x\text{HF}$ OR $\text{TeF}_6 + 6\text{H}_2\text{O} \rightarrow \text{Te}(\text{OH})_6 + 6\text{HF}$				1								

Question	Answer	Marks
1f(ii)	hydrolysis	1

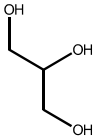
Question	Answer	Marks
2(a)	M1 (enthalpy change) when 1 mole of water is formed M2 from an (aqueous) acid and an alkali / (aqueous) base	2
2(b)(i)	0.05 mol	1
2(b)(ii)	M1 correct volume and correct temperature change M2 calculation to calculate Q based on M1 volume and temp and $Q = mc\Delta T$ $Q = mc\Delta T = 175 \times 4.18 \times (27.8 - 20) = (-)5705.7$ M3 energy change when 0.1 mol H_2O is made with appropriate unit and sign $\Delta H = M2 / 0.1 = -57.1 \text{ kJ mol}^{-1}$ OR $-57100 \text{ J mol}^{-1}$	3
2(c)(i)	..(1).. $H_2SO_4(aq)$ + ..(1).. $Ba(OH)_2(aq)$ → ... (1).. $BaSO_4(s)$ + $2H_2O(l)$ M1 correct state symbols for both products M2 correctly balanced equation	2
2(c)(ii)	precipitation (of $BaSO_4$) (also) involves an energy change	1

Question	Answer	Marks
3(a)	M1 appearance (colourless / yellow) liquid M2 structure and bonding simple / molecular AND covalent	2

Question	Answer				Marks
3(b)			MgCl_2	PCl_5	[1] [1] [1] [1]
	appearance		• (white) crystals / solid	• (white OR pale yellow) crystals / solid	
	one similarity in observation	(colourless) solution made			
	one difference in observation		no (misty / steamy) fumes	misty / steamy fumes	
	pH		• 6.5–7	• 0–4	
3(c)(i)	hot aqueous sodium hydroxide / hot NaOH(aq)				1
3(c)(ii)	oxidation number / state of <u>chlorine</u> / <u>Cl</u> increases / goes (from 0) to +5 AND decreases / goes (from 0) to –1				1
3(d)(i)	ultraviolet light				1
3(d)(ii)					[1] [1] [1]
		name of stage	equation		
		initiation	$\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$		
		propagation	$\text{CH}_2\text{Cl}_2 + \text{Cl}\cdot \rightarrow \text{CHCl}_2\cdot + \text{HCl}$		
		termination	$\text{CHCl}_2\cdot + \text{Cl}\cdot \rightarrow \text{CHCl}_3$		
3(e)	$\text{CHCl}_3 + 2\text{HF} \rightarrow \text{CHClF}_2 + 2\text{HCl}$				1
3(f)	M1 <i>m/e 164</i> $(\text{CF}_2^{35}\text{Cl}^{79}\text{Br})^+$ M2 <i>m/e 166</i> $(\text{CF}_2^{37}\text{Cl}^{79}\text{Br})^+$ AND $(\text{CF}_2^{35}\text{Cl}^{81}\text{Br})^+$				2

Question	Answer	Marks						
4(a)(i)	HO 	1						
4(a)(ii)	reducing agent	1						
4(b)(i)	cold dilute acidified KMnO ₄	1						
4(b)(ii)	CH ₂ O	1						
4(b)(iii)	<table border="1"> <tr> <td>type of hybridisation</td><td>sp²</td><td>sp³</td></tr> <tr> <td>number of carbon atoms in V</td><td>3</td><td>1</td></tr> </table>	type of hybridisation	sp ²	sp ³	number of carbon atoms in V	3	1	2
type of hybridisation	sp ²	sp ³						
number of carbon atoms in V	3	1						
4(c)	 M1 molecule with 5C atoms and 1 alcohol group M2 molecule with —CH(CH ₃)OH	2						

Question	Answer	Marks
5(a)(i)	$\text{C}_8\text{H}_{18} + 12\frac{1}{2} \text{O}_2 \rightarrow 8\text{CO}_2 + 9\text{H}_2\text{O}$ M1 correct formula of M C ₈ H ₁₈ M2 balanced equation showing complete combustion of M	2
5(a)(ii)	• C • CO • unburnt hydrocarbons • less/no CO₂ Two correct for one mark, three correct for two marks.	2
5(b)(i)	M1 • high temperature • high pressure • N ₂ M2 N ₂ + O ₂ → 2NO OR N ₂ + 2O ₂ → 2NO ₂ OR N ₂ + xO ₂ → 2NO _x	2

Question	Answer	Marks
5(b)(ii)	M1 NO ₂ is the catalyst (for SO ₂ → SO ₃) OR catalytic oxidation (of SO ₂) by NO ₂ M2 NO ₂ + SO ₂ → NO + SO ₃ AND 2NO + O ₂ → 2NO ₂ M3 SO ₃ reacts with rain OR moisture/water (in atmosphere) to form sulfuric acid / H ₂ SO ₄ OR SO ₃ + H ₂ O → H ₂ SO ₄	3
5(b)(iii)	photochemical smog / PAN	1
5(c)(i)	<i>suggest suitable reagent and conditions for step 1</i> heat AND any dilute named mineral acid e.g. dilute sulfuric acid / dilute hydrochloric acid	1
5(c)(ii)	 OR CH ₂ OHCH(OH)CH ₂ OH	1
5(c)(iii)	condensation	1
5(c)(iv)	methanol	1
5(c)(v)	methyl decanoate	1



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Question	Answer	Marks
1(a)(i)	bonding in magnesium – metallic AND bonding in sodium chloride – ionic	1
1(a)(ii)	bonds in NaCl are stronger than bonds in Mg	1
1(a)(iii)	M1 S ₈ / molecules of sulfur have more electrons (than P ₄ / molecules of phosphorus) M2 S has stronger instantaneous dipole–induced dipole forces (than phosphorus / P)	2
1(b)(i)	power of an atom to attract electrons to itself	1
1(b)(ii)	(across a period) • increase in nuclear charge • similar shielding • (so) increase in nuclear attraction for bonding / outer / valence electrons OR bonding / outer / valence electron(s) are more strongly attracted to nucleus Two correct for one mark, three correct for two marks	2
1(b)(iii)	hydrogen bond	1
1(b)(iv)	M1 link shown as a dashed line between the lone pair of electrons from N of one NH ₃ to one H on other NH ₃ M2 minimum 3 correct partial charges (on adjacent atoms) over two NH ₃ molecules EITHER $\delta^- \text{N} - \delta^+ \text{H} \cdots \delta^- \text{N}$ OR $\delta^+ \text{H} \cdots \delta^- \text{N} - \delta^+ \text{H}$	2
1(b)(v)	M1 O is more electronegative than N M2 two H-bonds per water molecule : 1 per ammonia molecule.	2

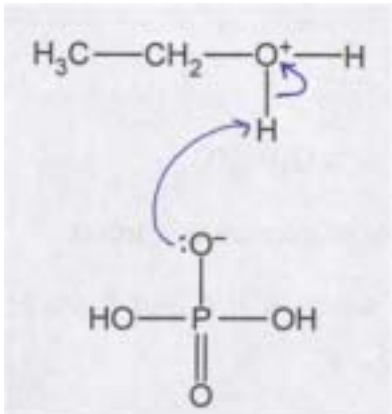
Question	Answer	Marks												
2(a)(i)	<table><tr><td>element</td><td>Na</td><td>Mg</td><td>Al</td><td>Si</td><td>P</td></tr><tr><td>maximum oxidation number of elements in chlorides</td><td>(+)1</td><td>(+)2</td><td>(+)3</td><td>(+)4</td><td>(+)5</td></tr></table> All correct for one mark	element	Na	Mg	Al	Si	P	maximum oxidation number of elements in chlorides	(+)1	(+)2	(+)3	(+)4	(+)5	1
element	Na	Mg	Al	Si	P									
maximum oxidation number of elements in chlorides	(+)1	(+)2	(+)3	(+)4	(+)5									
2(a)(ii)	number of outer/valence electrons	1												
2(b)(i)	$\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$	1												
2(b)(ii)	1–4	1												
2(c)(i)	$\text{PCl}_5 + 4\text{H}_2\text{O} \rightarrow 5\text{HCl} + \text{H}_3\text{PO}_4$	1												
2(c)(ii)	1–4	1												
2(d)(i)	$\text{Cl}_2 + \text{H}_2\text{O} \rightleftharpoons \text{HOCl} + \text{HCl}$	1												
2(d)(ii)	$3\text{Cl}_2 + 6\text{NaOH} \rightarrow 5\text{NaCl} + \text{NaClO}_3 + 3\text{H}_2\text{O}$	1												
2(e)(i)	ClO^-	1												
2(e)(ii)	$\text{NaClO} + \text{H}_2\text{O}_2 \rightarrow \text{O}_2 + \text{NaCl} + \text{H}_2\text{O}$	1												
2(e)(iii)	M1 (show how to calculate) mol O_2 gas 42 cm³ gas = 42 / 24000 mol oxygen gas (= 1.75 × 10⁻³ mol) M2 (process to find) amount NaClO in 10 cm³ sample = 100 cm³ (diluted) bleach M1 x 4 (= 4 × 1.75 × 10⁻³ mol in 10 cm³ = 0.007) M3 correct calculation using M2 to find concentration = (M2 /10) × 1000 × 74.5 = 52.2 (g / dm³)	3												

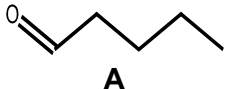
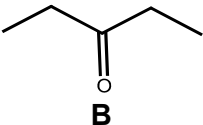
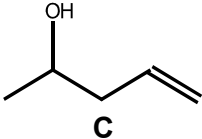
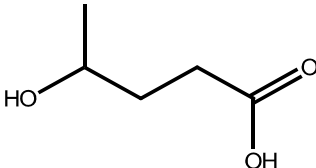
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Question	Answer	Marks						
3(a)(i)	KCN in ethanol + heat	1						
3(a)(ii)	propanenitrile	1						
3(a)(iii)	(acid) hydrolysis	1						
3(a)(iv)	2 CH ₃ CH ₂ COOH + Ca → (CH ₃ CH ₂ COO) ₂ Ca + H ₂ M1 H ₂ as product M2 balanced equation based on correct formula of Y	2						
3(b)	acid (conditions) / H ⁺ (aq) AND heat under reflux	1						
3(c)	<table><tr><td>type of bond in X</td><td>number of bonds in X</td></tr><tr><td>sigma σ</td><td>8</td></tr><tr><td>pi π</td><td>2</td></tr></table>	type of bond in X	number of bonds in X	sigma σ	8	pi π	2	2
type of bond in X	number of bonds in X							
sigma σ	8							
pi π	2							

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Question	Answer	Marks
4(a)	Method 1 • identification of number and type of bonds when all are broken $2\text{O-H} + 4\text{C-H} + \text{C}=\text{C}$ OR $(2 \times 460) + (4 \times 410) + 610$ • Identification of number and type of bonds when all are made $\text{O-H} + 5\text{C-H} + \text{C-C} + \text{C-O}$ OR $(460 + (5 \times 410) + 350 + 360)$ • calculation of energy to break bonds – energy to make bonds $3170 - 3220 = -50 \text{ (kJ mol}^{-1}\text{)}$ Two correct for one mark, three correct for two marks. OR Method 2 • identification of number and type of relevant bonds broken (including the new C-H only) $2\text{O-H} + \text{C}=\text{C}$ OR $(2 \times 460) + 610$ • identification of number and type of relevant bonds made (including the new C-H only) $\text{O-H} + \text{C-H} + \text{C-C} + \text{C-O}$ OR $(460 + 410 + 350 + 360)$ • calculation using energy to break bonds – energy to make bonds $1530 - 1580 = -50 \text{ (kJ mol}^{-1}\text{)}$ Two correct for one mark, three correct for two marks.	2
4(b)	M1 amount ethanol increases M2 equilibrium moves to right AND to produce fewer moles gas OR smaller amount of gas (to reduce the pressure)	2
4(c)(i)	acid AND it donates a proton / H^+	1
4(c)(ii)	$(\text{CH}_3\text{CH}_2)^+$ OR $\text{CH}_3\text{C}^+\text{H}_2$ AND accepts a pair of electrons	1

Question	Answer	Marks									
4(c)(iii)	 M1 arrow from bond of one of the O-H to O of the cation M2 arrow from lone pair on O of the anion to between H of H-O	2									
4(c)(iv)	M1 a catalyst increases rate of reaction M2 by producing an alternative reaction pathway with lower activation energy	2									
4(c)(v)	it is regenerated OR it is reformed	1									
4(c)(vi)	M1 (propan-2-ol is produced via a) more stable carbocation OR more stable intermediate OR $(\text{CH}_3)_2\text{C}^+\text{H}$ is more stable M2 (positive) inductive effect of more alkyl/methyl groups OR more electron donating alkyl / methyl groups OR greater electron donating effect of two alkyl / two methyl groups	2									
4(d)	<table border="1" data-bbox="660 1094 1617 1291"> <tr> <td></td><td>sigma</td><td>pi</td></tr> <tr> <td>type of orbitals involved in bond</td><td>$\text{sp}^2(-\text{sp}^2)$</td><td>$(2)\text{p}(-2)\text{p}$</td></tr> <tr> <td>how the orbitals overlap</td><td>direct</td><td>sideways</td></tr> </table> Two correct for one mark, four correct for two marks.		sigma	pi	type of orbitals involved in bond	$\text{sp}^2(-\text{sp}^2)$	$(2)\text{p}(-2)\text{p}$	how the orbitals overlap	direct	sideways	2
	sigma	pi									
type of orbitals involved in bond	$\text{sp}^2(-\text{sp}^2)$	$(2)\text{p}(-2)\text{p}$									
how the orbitals overlap	direct	sideways									

Question	Answer	Marks
5(a)	molecules / isomers with the same molecular formula / same number of atoms of each element AND different structural formulae / different structures	1
5(b)(i)	carbonyl (group)	1
5(b)(ii)	 	2
5(c)(i)	 M1 CH₃CH(OH) present M2 five carbons in a straight chain AND molecular formula C₅H₁₀O AND 1 C=C structure which shows only one type of stereoisomerism	2
5(c)(ii)	optical	1
5(d)(i)	ester	1
5(d)(ii)	condensation	1
5(d)(iii)		1

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Question	Answer				Marks
5(d)(iv)	Any two of the following differences in spectra D compared to E :				2
		bond	functional group	value or range of values of absorbance inclusive (cm ⁻¹)	
	E	C=O / C double bond to O	(ester)	1710–1750	
	D	C=O	(carboxy(l))	1670–1740	
	D	O-H OR OH bond	(carboxy(l))	2500–3000	
	D	O-H OR OH bond	(hydroxy(l) OR alcohol)	3200–3600	



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Cambridge International is publishing the mark schemes for the May/June 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

PUBLISHED**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

PUBLISHED**GENERIC MARKING PRINCIPLE 5:**

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

Science-Specific Marking Principles

1	Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
2	The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.
3	Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).
4	The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.
5	<u>'List rule' guidance</u> For questions that require <i>n</i> responses (e.g. State two reasons ...): • The response should be read as continuous prose, even when numbered answer spaces are provided. • Any response marked <i>ignore</i> in the mark scheme should not count towards <i>n</i>. • Incorrect responses should not be awarded credit but will still count towards <i>n</i>. • Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should not be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response. • Non-contradictory responses after the first <i>n</i> responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.

For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.

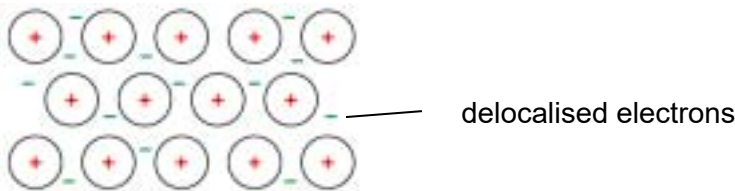
For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

7 Guidance for chemical equations

Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

Question	Answer	Marks
1(a)(i)	giant metallic	1
1(a)(ii)	 delocalised electrons M1 diagram showing minimum of 4 particles - circles containing just a + do not have to be labelled - empty circles / circles with Cu must be labelled + ion / positive ion / cation / Cu^{n+} AND with the circles surrounded by electrons shown as e^- / – OR little circles labelled delocalised electrons	1
1(b)(i)	(the mass of) one twelfth of the mass of a C-12 / ^{12}C atom (or isotope)	1
1(b)(ii)	average mass of the isotopes of an element compared to the unified atomic mass unit	1
1(b)(iii)	$(62.93 \times 69.15) \div 100 + (64.928 \times 30.85) \div 100 = 63.55 / 63.546$	1
1(c)	$^{63}\text{Cu}^{2+}$	1
1(d)(i)	$2\text{Cu}^{2+} + 4\text{I}^- \rightarrow 2\text{CuI} + \text{I}_2$	1
1(d)(ii)	Cu^{2+} OR CuSO_4 AND copper (species / ion) has gained / taken electron(s) from iodide (ion)	1
1(d)(iii)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 4s^0$	1

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Question	Answer	Marks
2(a)(i)	it / aluminium oxide is insoluble (in water) OR it / aluminium oxide does not react (with water)	1
2(a)(ii)	M1 correct state of correct aluminium product M2 balanced equation for reaction of aluminium oxide with NaOH $\text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaAl}(\text{OH})_4(\text{aq})$ OR $\text{Al}_2\text{O}_3 + 2\text{NaOH} \rightarrow 2\text{NaAlO}_2(\text{aq}) + \text{H}_2\text{O}$	2
2(a)(iii)	sodium (only)	1
2(b)	$\text{Mg}(\text{NO}_3)_2$	1
2(c)(i)	Al (+)3 / III AND P (+)5 / V	1
2(c)(ii)	different number of valence/outer shell electrons	1
2(c)(iii)	$\text{PCl}_5 + 4\text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + 5\text{HCl}$	1
2(c)(iv)	hydrolysis / substitution	1
2(c)(v)	$\text{HCl}(\text{g})$ dissolves in water to make (hydrochloric) acid	1

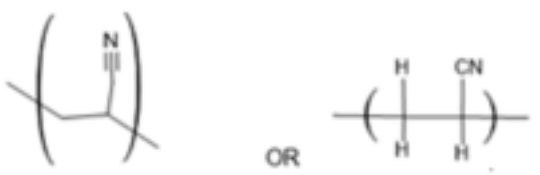
Question	Answer	Marks
3(a)	M1 (energy change) when 1 mole of water is formed M2 from an (aqueous) acid and an alkali / aqueous base	2
3(b)(i)	0.05 mol ($\text{H}_2\text{SO}_4(\text{aq})$)	1
3(b)(ii)	M1 correct value for Q (using 0.1 mol H_2O / OR $2 \times (b)(i)$) (and Q in Joules) M2 calculate ΔT (using their Q AND 110) $Q/mc = \Delta T = (Q) \div (4.18 \times 110) = 12.42$ ($^{\circ}\text{C}$) M3 use ΔT and initial temperature to find temperature of final solution $21.4 + M2 = 33.8$ ($^{\circ}\text{C}$) [$M3 \Delta T + 21.4 = T_{\text{max}}$]	3
3(c)(i)	$\text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}$	1
3(c)(ii)	(additional) energy is involved / required to fully ionise / dissociate (weak / ethanoic acid) OR (additional) energy is involved / required to donate/ release H^+ ions	1

Question	Answer	Marks
4(a)(i)	$2\text{KCl} + \text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + 2\text{HCl}$ OR $\text{KCl} + \text{H}_2\text{SO}_4 \rightarrow \text{KHSO}_4 + \text{HCl}$	1

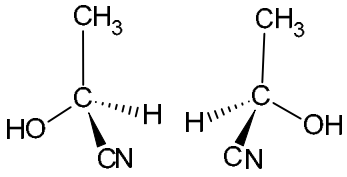
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Question	Answer	Marks
4(a)(ii)	M1 HI(g) is not the only gaseous product OR SO₂ and / or H₂S and / or I₂(g) is (also) made M2 HI / iodide (ion) is oxidised OR H₂SO₄ oxidises HI OR HI reduces sulfuric acid	2
4(b)(i)	(from colourless) to purple	1
4(b)(ii)	$K_C = [\text{H}_2][\text{I}_2] / [\text{HI}]^2$ OR $0.0217 = [\text{H}_2][\text{I}_2] / [\text{HI}]^2$	1
4(b)(iii)	M1 [HI] at equilibrium = $1.7 / 2 = 0.85$ M2 idea that $[\text{H}_2] = [\text{I}_2]$ in equilibrium mixture M3 correct calculation based on correct rearrangement of equation in (b)(ii), 0.0217 and their M1 = 0.125	3
4(c)(i)	new mixture will have a lower / smaller conc / amount of H ₂ and I ₂	1
4(c)(ii)	endothermic AND decrease in temperature causes position of equilibrium to shift in exothermic direction	1

Question	Answer	Marks												
5(a)	$\text{C}_3\text{H}_7\text{O}$	1												
5(b)(i)	$\text{C}_6\text{H}_{10}\text{O}_3 + [6\text{H}] \rightarrow \text{C}_6\text{H}_{14}\text{O}_2 + \text{H}_2\text{O}$	1												
5(b)(ii)	LiAlH_4 (in dry ether)	1												
5(c)	<table border="1"> <tr> <td>type of hybridisation</td><td>sp^2</td><td>sp^3</td></tr> <tr> <td>number of carbon atoms in X</td><td>2</td><td>4</td></tr> </table>	type of hybridisation	sp^2	sp^3	number of carbon atoms in X	2	4	2						
type of hybridisation	sp^2	sp^3												
number of carbon atoms in X	2	4												
5(d)	<table border="1"> <tr> <td>reagent</td><td>observation on addition to X</td><td>observation on addition to Y</td></tr> <tr> <td>sodium carbonate solution</td><td>effervescence</td><td>no change</td></tr> <tr> <td>2,4-DNPH</td><td>orange precipitate</td><td>no change</td></tr> <tr> <td>alkaline aqueous iodine</td><td>yellow precipitate</td><td>yellow precipitate</td></tr> </table> Two correct for one mark, four correct for two marks, six correct for three marks	reagent	observation on addition to X	observation on addition to Y	sodium carbonate solution	effervescence	no change	2,4-DNPH	orange precipitate	no change	alkaline aqueous iodine	yellow precipitate	yellow precipitate	3
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sodium carbonate solution	effervescence	no change												
2,4-DNPH	orange precipitate	no change												
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Question	Answer	Marks
6(a)		1
6(b)(i)	nucleophilic addition	1

Question	Answer	Marks
6(b)(ii)	M1 correct dipole on C=O AND curly arrow from C=O bond to O AND from lone pair of electrons on C of :CN⁻ M2 correct intermediate (charge on O or overall) M3 curly arrow from lone pair of electrons on O to H⁺ AND correct organic product (+ CN⁻)	3
6(b)(iii)	heat + conc. sulfuric acid / conc. phosphoric acid OR heat + Al ₂ O ₃	1
6(b)(iv)	S C≡N AND T C=C	1
6(c)(i)	(molecules / compounds with the) same structural formula (and same molecular formula) with different arrangement of atoms / groups in space	1
6(c)(ii)	M1 restricted rotation of C=C (bond) M2 each C of the double bond has two different groups / two different atoms (attached)	2

Question	Answer	Marks
6(d)	 A pair of molecules of 2-hydroxypropanenitrile with bonds represented in 3-d AND the pair of molecules are non-superimposable images	1
6(e)	$\text{CH}_3\text{CH}_2\text{CN} + 2\text{H}_2 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$	1
6(f)(i)	substitution	1
6(f)(ii)	M1 ammonia / NH_3 M2 heat + (M1 in ethanol) under pressure	2