OXFORD
INTERNATIONAL
AQA EXAMINATIONS

INTERNATIONAL A-LEVEL

CHEMISTRY (9620)

CH03

Unit 3 Inorganic 2 and Physical 2

Mark scheme

June 2022

Version: 1.0 Final

226XCH03/MS

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this mark scheme are available from oxfordaqaexams.org.uk

A-level Chemistry
Mark Scheme Instructions for Examiners

1. General

The mark scheme for each question shows:

- the marks available for each part of the question
- the total marks available for the question
- the typical answer or answers which are expected
- extra information to help the examiner make his or her judgement and help to delineate what is acceptable or not worthy of credit or, in discursive answers, to give an overview of the area in which a mark or marks may be awarded.

The extra information in the 'Comments' column is aligned to the appropriate answer in the left-hand part of the mark scheme and should only be applied to that item in the mark scheme.

You should mark according to the contents of the mark scheme. If you are in any doubt about applying the mark scheme to a particular response, consult your Team Leader.

At the beginning of a part of a question a reminder may be given, for example: where consequential marking needs to be considered in a calculation; or the answer may be on the diagram or at a different place on the script.

In general the right-hand side of the mark scheme is there to provide those extra details which might confuse the main part of the mark scheme yet may be helpful in ensuring that marking is straightforward and consistent.

The use of M1, M2, M3 etc in the right-hand column refers to the marking points in the order in which they appear in the mark scheme. So, M1 refers to the first marking point, M2 the second marking point etc.

2. Emboldening

2.1 In a list of acceptable answers where more than one mark is available 'any **two** from' is used, with the number of marks emboldened. Each of the following bullet points is a potential mark.

2.2 A bold **and** is used to indicate that both parts of the answer are required to award the mark.

2.3 Alternative answers acceptable for a mark are indicated by the use of **OR**. Different terms in the mark scheme are shown by a / ; eg allow smooth / free movement.

3. Marking points

3.1 Marking of lists

This applies to questions requiring a set number of responses, but for which students have provided extra responses. The general 'List' principle to be followed in such a situation is that 'right + wrong = wrong'.

Each error / contradiction negates each correct response. So, if the number of error / contradictions equals or exceeds the number of marks available for the question, no marks can be awarded.

However, responses considered to be neutral (often prefaced by 'Ignore' in the mark scheme) are not penalised.

For example, in a question requiring 2 answers for 2 marks:

Correct answers	Incorrect answers (ie incorrect rather than neutral)	Mark (2)	Comment
1	0	1	
1	1	1	They have not exceeded the maximum number of responses so there is no penalty.
1	2	0	They have exceeded the maximum number of responses so the extra incorrect response cancels the correct one.
2	0	2	
2	1	1	
2	2	0	
3	0	2	The maximum mark is 2
3	1	1	The incorrect response cancels out one of the two correct responses that gained credit.
3	2	0	Two incorrect responses cancel out the two marks gained.
3	3	0	

3.2 Marking procedure for calculations

Full marks should be awarded for a correct numerical answer, without any working shown, unless the question states 'Show your working' or 'justify your answer'. In this case, the mark scheme will clearly indicate what is required to gain full credit.

If an answer to a calculation is incorrect and working is shown, process mark(s) can usually be gained by correct substitution / working and this is shown in the 'Comments' column or by each stage of a longer calculation.

3.3 Errors carried forward, consequential marking and arithmetic errors

Allowances for errors carried forward are most likely to be restricted to calculation questions and should be shown by the abbreviation ECF or consequential in the marking scheme.

An arithmetic error should be penalised for one mark only unless otherwise amplified in the marking scheme. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value from data given in a question.

3.4 Equations

In questions requiring students to write equations, state symbols are generally ignored unless otherwise stated in the 'Comments' column.

Examiners should also credit correct equations using multiples and fractions unless otherwise stated in the 'Comments' column.

3.5 Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

3.6 Interpretation of 'it'

Answers using the word 'it' should be given credit only if it is clear that the 'it' refers to the correct subject.

3.7 Phonetic spelling

The phonetic spelling of correct scientific terminology should be credited **unless** there is a possible confusion with another technical term or if the question requires correct IUPAC nomenclature.

3.8 Brackets

(…..) are used to indicate information which is not essential for the mark to be awarded but is included to help the examiner identify the sense of the answer required.

3.9 Ignore / Insufficient / Do not allow

Ignore or insufficient is used when the information given is irrelevant to the question or not enough to gain the marking point. Any further correct amplification could gain the marking point.

Do **not** allow means that this is a wrong answer which, even if the correct answer is given, will still mean that the mark is not awarded.

3.10 Marking crossed out work

Crossed out work that **has not been** replaced should be marked as if it were not crossed out, if possible. Where crossed out work **has been** replaced, the replacement work and not the crossed out work should be marked.

3.11 Reagents

The command word "Identify", allows the student to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (eg for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.

For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a student provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

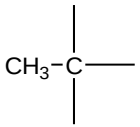
3.12 Organic structures

Where students are asked to draw organic structures, unless a specific type is required in the question and stated in the mark scheme, these may be given as displayed, structural or skeletal formulas or a combination of all three as long as the result is unambiguous.

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Skeletal formulae must show carbon atoms by an angle or suitable intersection in the skeleton chain. Functional groups must be shown and it is essential that all atoms other than C atoms are shown in these (except H atoms in the functional groups of aldehydes, secondary amines and N-substituted amides which do not need to be shown).
- Structures must not be ambiguous, e.g. 1-bromopropane should be shown as $CH_3CH_2CH_2Br$ and not as the molecular formula C_3H_7Br which could also represent the isomeric 2-bromopropane.
- Bonds should be drawn correctly between the relevant atoms. This principle applies in all cases where the attached functional group contains a carbon atom, eg nitrile, carboxylic acid, aldehyde and acid chloride. The carbon-carbon bond should be clearly shown. Wrongly bonded atoms will be penalised **on every occasion**. (see the examples below)
- The same principle should also be applied to the structure of alcohols. For example, if students show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in alkyl groups, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Similar latitude should be given to the representation of amines where NH_2─ C will be allowed, although H_2N─ C would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or vertical C ─ NH_2 bonds should **not** be penalised. For other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.

By way of illustration, the following would apply.



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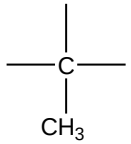

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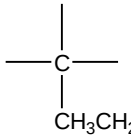

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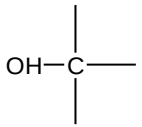

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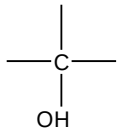

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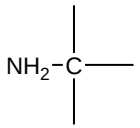

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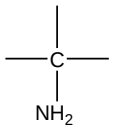

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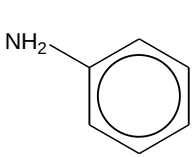

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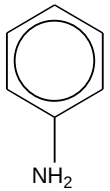

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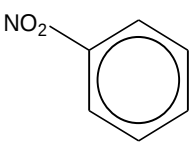

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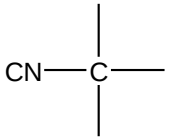

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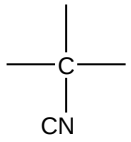

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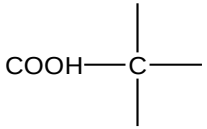

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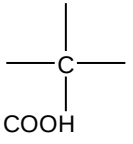

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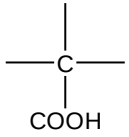

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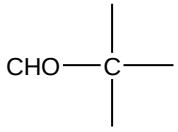

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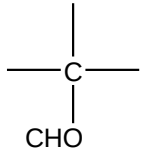

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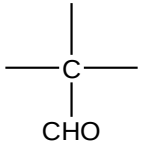

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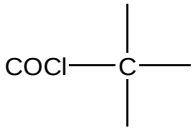

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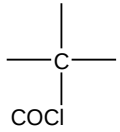


not allowed

- Representation of CH_2 by $C–H_2$ will be penalised
- Some examples are given here of **structures** for specific compounds that should **not** gain credit (but, exceptions may be made in the context of balancing equations)

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

- In most cases, the use of “sticks” to represent C ─ H bonds in a structure should **not** be penalised. The exceptions to this when “sticks” will be penalised include
  - structures in mechanisms where the C ─ H bond is essential (e.g. elimination reactions in halogenoalkanes and alcohols)
  - when a displayed formula is required
  - when a skeletal structure is required or has been drawn by the candidate

3.13 Organic names

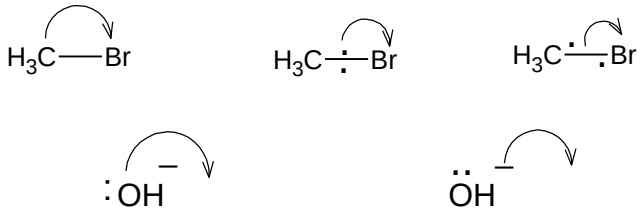
As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit. Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**
ethan-1,2-diol	should be **ethane-1,2-diol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**
3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

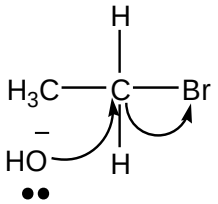
3.14 Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.

The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

- the absence of a radical dot should be penalised **once only** within a clip.
- the use of half-headed arrows is not required, but the use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

The correct use of skeletal formulae in mechanisms is acceptable, but where a C-H bond breaks both the bond and the H must be drawn to gain credit.

Question	Marking guidance	Mark	Comments
01.1	Method 1 Top line : $Na^+(g) + e^- + ½F_2(g)$ Lower line : $Na(g) + ½F_2(g)$ Method 2 Top line : Na(g) + F(g) Lower line : Na(s) + F(g) Method 3 Top line : Na(g) + F(g) Lower line : $Na(g) + ½F_2(g)$	1 1	Mark only one method / do not mix and match

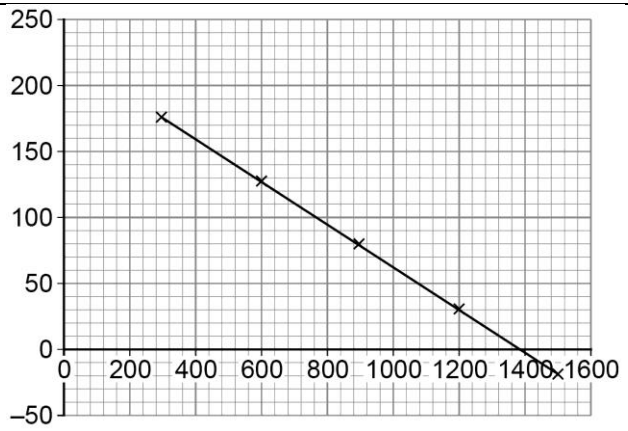
Question	Marking guidance	Mark	Comments
01.2	$\Delta_f H$ (NaF) = +109 + 494 + (158÷2) - 348 - 902 $\Delta_f H$ (NaF) = -568 (kJ mol^{-1})	1 1	 If missing ÷2 then allow M2 for –489; +568 scores zero

Question	Marking guidance	Mark	Comments
01.3	Theoretical lattice enthalpy value assumes only ionic interaction / point charges / no covalent / perfect spheres / perfectly ionic OR Because the experimental/Born-Haber value allows for/includes covalent interaction / non–spherical ions / distorted ions / polarisation (that strengthens the lattice)	1	 allow there is some covalent character in NaF

Question	Marking guidance	Mark	Comments
01.4	The value for sodium chloride is less endothermic.	1	

Question	Marking guidance	Mark	Comments
01.5	ΔH_{soln} NaF = LE + ($\Delta H_{hyd}Na^{+}$) + ($\Delta H_{hyd}F^{-}$) = 902 + (–406) + (–506) = –10 kJ mol^{-1}	1 1	 If –1814 then allow 1 mark

Total		8	

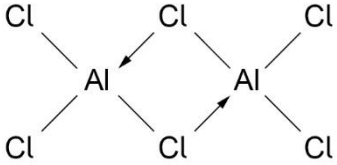
Question	Marking guidance	Mark	Comments
02.1		2	M1 All points plotted correctly M2 Straight line of best fit: must not be doubled or kinked.

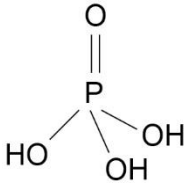
Question	Marking guidance	Mark	Comments
02.2	M1 Gradient = $\Delta y/\Delta x$ = –0.16(3) M2 ΔS = – Gradient ΔS = 0.16(3) kJ K^{-1} mol^{-1} Or ΔS = 163 J K^{-1} mol^{-1} M3 = Units to match value	1 1 1	 Allow this mark ECF on their graph

Question	Marking guidance	Mark	Comments
02.3	Temperature = 1400 (K)	1	ECF on graph in 02.1 and ECF on gradient in 02.2

Total		6	

Question	Marking guidance	Mark	Comments
03.1	Observations: Yellow/orange flame/light White powder/solid Equation: $4\,Na + O_2 \rightarrow 2\,Na_2O$	 1 1 1	 Ignore white ppt. Allow white fumes Allow multiples Ignore state symbols

Question	Marking guidance	Mark	Comments
03.2	Structure of Al_2Cl_6 drawn  	1 1	M1 structure M2 2 correct co-ordinate bonds from Cl to Al

Question	Marking guidance	Mark	Comments
03.3	Equation $P_4O_{10} + 6\,H_2O \rightarrow 4\,H_3PO_4$ Structure of H_3PO_4 drawn  	1 1	Allow multiples; ignore state symbols Do not allow equations from P_2O_5 Accept 2D or 3D

Question	Marking guidance	Mark	Comments
03.4	$n(SiCl_4) = \frac{0.750}{170.1} = 0.00441$ mol n(NaOH) = 0.00441 x 4 = 0.0176 mol volume of NaOH = $\frac{0.0176 \times 1000}{0.500} = 35.27\ cm^3$	1 1 1	 M2 = M1 × 4 M3 = M2 × 2000 Allow answers to 2 sf or more

Question	Marking guidance	Mark	Comments
03.5	SiO_2 is macromolecular / has a giant covalent structure Many/Strong covalent bonds (need to be broken) / covalent bonds require lots of energy to overcome $SiCl_4$ has a (covalent) molecular structure The van der Waals forces <u>between the molecules</u> are weak / The van der Waals forces <u>between the molecules</u> are easily broken / The van der Waals forces <u>between the molecules</u> need little energy to break	1 1 1 1	 If between molecules then lose M2 If breaking covalent bonds then lose M4

Total		14	

Question	Marking guidance	Mark	Comments
04.1	$n(MnO_4^-) = \frac{22.50 \times 0.0150}{1000} = 3.375 \times 10^{-4}$ mol	1	
	$n(Fe^{2+}) = 3.375 \times 10^{-4} \times 5 = 1.6875 \times 10^{-3}$ mol	1	M1 × 5
	$n(Fe^{2+}$ in 250 $cm^3) = 1.6875 \times 10^{-3} \times 10 = 1.6875 \times 10^{-2}$ mol	1	M2 × 10
	$M_r = \frac{6.615}{1.6875 \times 10^{-2}} = 392.0$	1	6.615 ÷ M3
	$x = \frac{392.0-284.0}{18.0} = 6$	1	Must be a whole number For M4 and M5: accept other correct alternative methods such as via calculating the moles of water present in the crystals and then calculating empirical formula (M2 and M3 can be in either order)

Question	Marking guidance	Mark	Comments
04.2	$KMnO_4$ is now in excess / MnO_4^- ions are now in excess	1	

Question	Marking guidance	Mark	Comments
04.3	Reagent: NaOH / KOH	1	
	Observation for NH_4^+ : gas formed that turns (damp red) litmus blue / (damp red) litmus held at mouth of tube turns blue.	1	Allow (pungent) gas formed Do not allow put damp litmus paper <u>in</u> the test-tube
	Observation for Fe^{2+} : green ppt	1	

Total		**9**	

Question	Marking guidance	Mark	Comments
05.1	(Central) metal ion surrounded by (co-ordinately bonded) ligands	1	allow number of co-ordinate bonds exceeds oxidation state of the metal

Question	Marking guidance	Mark	Comments
05.2	$[Cu(H_2O)_6]^{2+} + 4\,Cl^- \rightleftharpoons [CuCl_4]^{2-} + 6\,H_2O$ There is a change in ligand / there is a change in coordination number	1 1	Ignore state symbols / allow multiples

Question	Marking guidance	Mark	Comments
05.3	Blue precipitate $[Cu(H_2O)_6]^{2+} + 2\,OH^- \rightarrow [Cu(H_2O)_4(OH)_2] + 2\,H_2O$	1 1	 Ignore state symbols /allow multiples

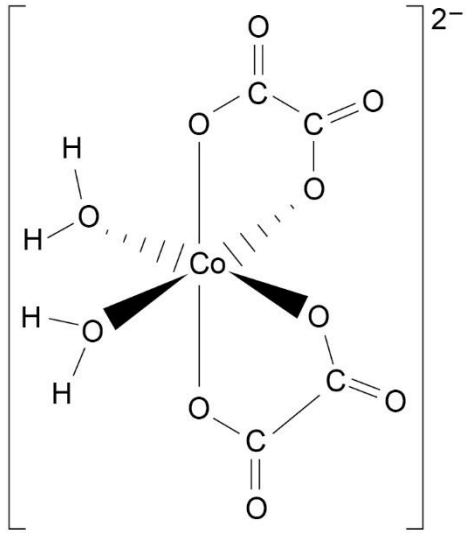
Question	Marking guidance	Mark	Comments
05.4	(after a few drops) a blue precipitate is formed (in excess) deep blue solution $[Cu(H_2O)_6]^{2+} + 4\,NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4\,H_2O$	1 1 1	 Ignore state symbols /allow multiples

Total		**8**	

Question	Marking guidance	Mark	Comments
06.1	$\Delta E = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{535 \times 10^{-9}}$ $\Delta E = 3.72 \times 10^{-19}$ J	1 1	Inserting numbers and conversion of wavelength Answer

Question	Marking guidance	Mark	Comments
06.2	Change the pH Change the ligand	1 1	Allow change the temperature

Question	Marking guidance	Mark	Comments
06.3	$[Co(NH_3)_6]^{2+} + 3\,H_2NCH_2CH_2NH_2 \rightarrow [Co(H_2NCH_2CH_2NH_2)_3]^{2+} + 6\,NH_3$	1	
	Increase in the number of particles / 4 → 7	1	If numbers given then they must be correct
	increase in disorder / ΔS is positive / entropy increases	1	
	Same number and type of bonds broken and formed	1	
	So, ΔH approximately 0 (So ΔG is <0)	1	

Question	Marking guidance	Mark	Comments
06.4	(water groups should be in the cis-positions: 90° from each other) 	1	Ignore missing charge

Total		**10**	

Question	Marking guidance	Mark	Comments
07.1	$Cu^{2+}(aq)$	1	Allow Copper(II)
	$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$	1	Ignore state symbols Allow Species = Fe^{3+} Equation = $2Fe^{3+} + Fe \rightarrow 3Fe^{2+}$

Question	Marking guidance	Mark	Comments
07.2	EMF = 1.52 – 1.07 = 0.45 (V)	+1	
	$2\,BrO_3^-(aq) + 12\,H^+(aq) + 10\,Br^-(aq)$	1	M2 – correct species on each side
	$\rightarrow 6\,H_2O(l) + 6\,Br_2(aq)$	1	M3 – correct balancing.
			Ignore state symbols / allow multiples.

Question	Marking guidance	Mark	Comments
07.3	M1 To complete the circuit / allows the flow of ions between cells	1	Do not accept electrons
	M2 Allow any soluble salt which will not react with species in either cell. Eg KNO_3	1	

Question	Marking guidance	Mark	Comments
07.4	M1 Platinum M2 Will not react with any of the species in either cell.	1 1	Allow graphite Allow inert / unreactive M2 dependent on M1 unless M1 missing

Question	Marking guidance	Mark	Comments
07.5	EMF is unchanged.	1	

Total		10	

Question	Marking guidance	Mark	Comments
08.1	(pH =) $-\log[H^+]$	1	

Question	Marking guidance	Mark	Comments
08.2	$n(HCl) = \frac{0.115 \times 20}{1000} = 2.30 \times 10^{-3}$ mol $[H^+] = \frac{2.30 \times 10^{-3} \times 1000}{145} = 0.0159$ mol dm^{-3} pH = –log (0.0159) = 1.80	1 1 1	 pH = –log(M2) At least 1 dp

Question	Marking guidance	Mark	Comments
08.3	$[H^+] = \sqrt{K_w} = 2.00 \times 10^{-7}$ pH = $-\log(2.00 \times 10^{-7}) = 6.70$	1 1	 M2 dependent on M1 At least 1 dp

Question	Marking guidance	Mark	Comments
08.4	$[H^+] = \sqrt{K_a[CH_3CH_2CH_2COOH]}$ or $[H^+] = \sqrt{1.51 \times 10^{-5} \times 0.175}$ $[H^+] = 1.63 \times 10^{-3}$ mol dm^{-3} pH = 2.79	1 1 1	M1 for rearranged expression with or without numbers inserted pH = –log(M2) 2 dp essential

Question	Marking guidance	Mark	Comments
08.5	Thymolphthalein	1	

Question	Marking guidance	Mark	Comments
08.6	$[H^+] = 10^{-pH} = 10^{-4.50} = 3.16 \times 10^{-5}$ mol dm^{-3}	1	Allow Henderson-Hasselbalch equation
	[sodium butanoate] = $\frac{K_a\ [\text{butanoic acid}]}{[H^+]}$ OR [sodium butanoate] = $\frac{1.51 \times 10^{-5}\ [0.175]}{[3.16 \times 10^{-5}]}$	1	M2 – in words or numbers; allow K_a expression
	[sodium butanoate]=0.0836 mol dm^{-3}	1	alternative to M3 and M4 M3: n(butanoic acid) = $\frac{50.0 \times 0.175}{1000}$ = 8.75×10^{-3} mol
	n(sodium butanoate) = $\frac{0.0836 \times 50.0}{1000}$ = 4.18×10^{-3} mol	1	M4 = n(sodium butanoate)= $\frac{1.51 \times 10^{-5}\ [8.75 \times 10^{-3}]}{[3.16 \times 10^{-5}]}$ = 4.18×10^{-3} mol
	Mass = n x M_r = $4.18 \times 10^{-3} \times 110$ = 0.46(0)g	1	

Total		15	