OXFORD

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INTERNATIONAL A-LEVEL CHEMISTRY (9620)

CH03

Unit 3: Inorganic 2 and Physical 2

Mark scheme

June 2023

Version: 1.0 Final

2 3 6 X C H 0 3 / M S

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.

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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.

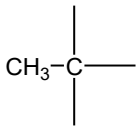
3.12 Organic structures

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.

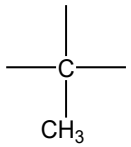
In general

- 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.

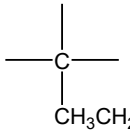
By way of illustration, the following would apply.



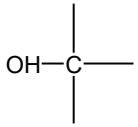
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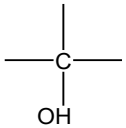
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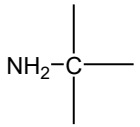
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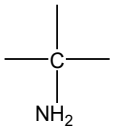
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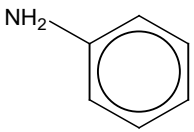
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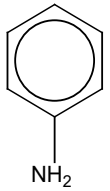
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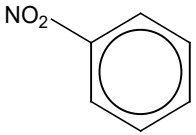
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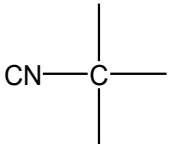
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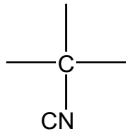
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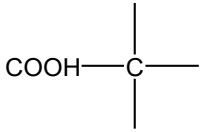
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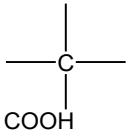
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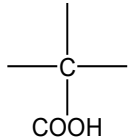
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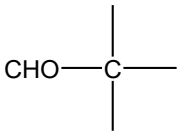
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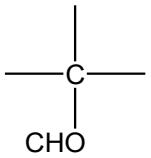
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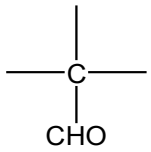
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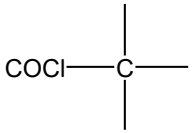
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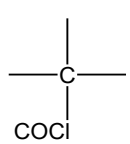
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- Representation of CH_2 by $C–H_2$ will be penalised
- Some examples are given here of **structures** for specific compounds that should **not** gain credit (but, exceptions may be made in the context of balancing equations)

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

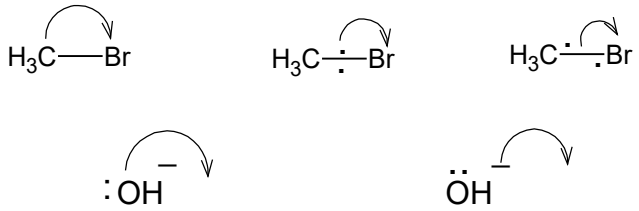
As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit. Some illustrations are given here.

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**

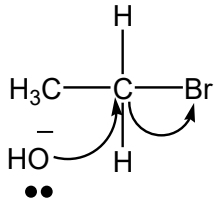
3.14 Organic reaction mechanisms

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.

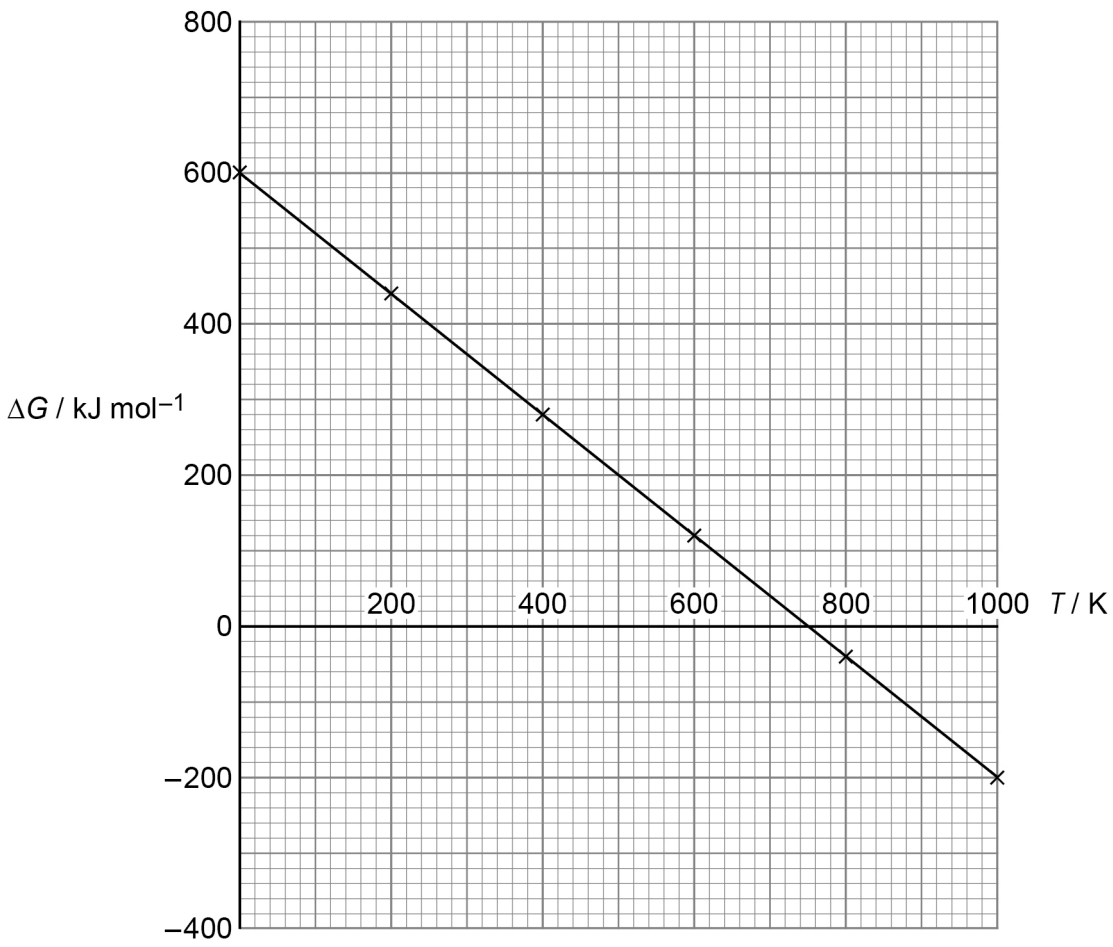
Question	Marking guidance	Mark	Comments
01.1	$Mg^{2+}(g) + 2e^- + O(g)$	1	state symbols essential in all
	$Mg^{2+}(g) + e^- + O^-(g)$	1	
	$Mg^+(g) + e^- + O(g)$	1	

Question	Marking guidance	Mark	Comments
01.2	$\Delta_f H$ (MgO) + $\Delta_L H$ (MgO) = $\Delta_a H$ (Mg) + $\Delta_a H$ (O) + $\Delta_i H$ (Mg) + $\Delta_i H$ (Mg^+) + $\Delta_{ea} H$ (O) + $\Delta_{ea} H$ (O^-) **or** $\Delta_L H$ (MgO) = 150 + 248 + 736 + 1450 – 142 + 844 + 602	1	
	$\Delta_L H$ (MgO) = +3888 kJ mol^{-1}	1	allow 1 for –3888 kJ mol^{-1} allow 1 for +3764 kJ mol^{-1} (incorrectly used $\frac{1}{2}$ × 248)

Question	Marking guidance	Mark	Comments
01.3	the barium ion is larger than the magnesium ion **or** Ba^{2+} has a lower charge density than Mg^{2+}	1	allow converse for Mg^{2+}
	there is a weaker attraction for the oxide ion **or** there is a weaker attraction between the oppositely charged ions	1	

Question	Marking guidance	Mark	Comments
01.4	the (negative) electron and the O^- will repel	1	the (negative) electron and the negative ion will repel

Total		**8**	

Question	Marking guidance	Mark	Comments
02.1	 plot points (1) straight line of best fit (1)	2	points within ± 1 small square line should be straight and must not be doubled or kinked

Question	Marking guidance	Mark	Comments
02.2	ΔH = 600 kJ mol^{-1} (check graph)	1	using candidate's graph in question **02.1** correctly reads off value that line crosses y-axis (when T=0)

Question	Marking guidance	Mark	Comments
02.3	M1 (calculates gradient =) –0.8 M2 (ΔS = gradient × –1 =) (+)0.8 (kJ K^{-1} mol^{-1}) M3 (multiplies × 1000 =) (+)800 (J K^{-1} mol^{-1})	1 1 1	using candidate's graph in question **02.1** correctly calculates gradient M2 = M1 × –1 M3 = M2 × 1000 **Alternative method** M1: selects point from graph and uses in $\Delta G=\Delta H-T\Delta S$ M2: calculates ΔS in kJ K^{-1} mol^{-1} M3: M2 × 1000

Question	Marking guidance	Mark	Comments
02.4	750 (value to be confirmed when graph is inserted) (K) **or** T = (ΔH from part **02.2**) ÷ (ΔS from part **02.3** × 10^{-3})	1	using candidate's graph in question **02.1** correctly reads point that line crosses x-axis using alternative data: (T = $\frac{105}{140 \times 10^{-3}}$ =) 750 (K)

Total		7	

Question	Marking guidance	Mark	Comments
03.1	the concentration of water is effectively constant **or** the concentration of water does not change very much **or** the concentration of water is very high	1	

Question	Marking guidance	Mark	Comments
03.2	$[H_3O^+]$ (= $\sqrt{K_a[CH_3CH_2COOH]}$ = $\sqrt{1.34 \times 10^{-5} \times 0.150}$ =) 1.42×10^{-3} ($mol\,dm^{-3}$) pH = 2.85	1 1	 must be 2 decimal places M2 = – log M1

Question	Marking guidance	Mark	Comments
03.3	M1 $[H_3O^+]$ (= $10^{-5.06}$) = 8.71×10^{-6} (mol dm^{-3}) M2 $[CH_3CH_2COONa] = K_a \times \frac{[CH_3CH_2COOH]}{[H_3O^+]}$ M3 $[CH_3CH_2COONa] (= 1.34 \times 10^{-5} \times \frac{0.150}{8.71 \times 10^{-6}}) = 0.231$ (mol dm^{-3}) M4 $n(CH_3CH_2COONa) (= 0.231 \times \frac{100}{1000}) = 0.0231$ (mol) M5 mass(CH_3CH_2COONa) (= 0.0231 × 96.0) = 2.22 (g)	1 1 1 1 1	 M3 = $1.34 \times 10^{-5} \times \frac{0.150}{M1}$ M4 = M3 × $\frac{100}{1000}$ M5 = M4 × 96.0 **Alternative Method** M1 $[H_3O^+]$ (= $10^{-5.06}$) = 8.71×10^{-6} (mol dm^{-3}) M2 $n(CH_3CH_2COOH) = 0.0150$ (mol) **and** $n(H_3O^+) = 8.71 \times 10^{-7}$ (mol) M3 $n(CH_3CH_2COONa) = K_a \times \frac{n(CH_3CH_2COOH)}{n(H_3O^+)}$ M4 $n(CH_3CH_2COONa) = 0.0231$ (mol) M5 mass(CH_3CH_2COONa) (= 0.0231 × 96.0) = 2.22 (g)

Question	Marking guidance	Mark	Comments
03.4	Phenol red	1	

Total		9	

Question	Marking guidance	Mark	Comments
04.1	+3	1	

Question	Marking guidance	Mark	Comments
04.2	$Li^+ + e^- \rightarrow Li$ E = –3.00 V	1 1	allow multiples; ignore state symbols must be negative

Question	Marking guidance	Mark	Comments
04.3	unreactive (with the electrolyte) / inert conducts electricity	1 1	Ignore references to cost

Total		5	

Question	Marking guidance	Mark	Comments
05.1	Condition: heat (strongly) in steam	1	
	Observations: white/bright light/flame	1	do not accept precipitate ignore black solid
	white solid/powder/ash formed	1	
	Equation: $Mg + H_2O \rightarrow MgO + H_2$	1	ignore state symbols

Question	Marking guidance	Mark	Comments
05.2	heat evolved / violent reaction	1	
	(white solid reacts to form) a colourless solution	1	
	$P_4O_{10} + 6\,H_2O \rightarrow 4\,H_3PO_4$	1	do not accept P_2O_5

Question	Marking guidance	Mark	Comments
05.3	$2\,Al + 3\,Cl_2 \rightarrow Al_2Cl_6$	1	allow $2\,AlCl_3$

Question	Marking guidance	Mark	Comments
05.4	(sodium chloride) giant ionic (lattice)	1	
	strong (electrostatic) forces of attraction between Na^+ and Cl^- / oppositely charged ions	1	if molecules mentioned lose M2
	(silicon(IV) chloride) (simple) molecular	1	
	weak van der Waals' forces <u>between molecules</u>	1	allow: weak London forces <u>between molecules</u> weak induced dipole-dipole forces <u>between molecules</u> weak dispersion forces <u>between molecules</u>

Question	Marking guidance	Mark	Comments
05.5	7	1	

Question	Marking guidance	Mark	Comments
05.6	1	1	

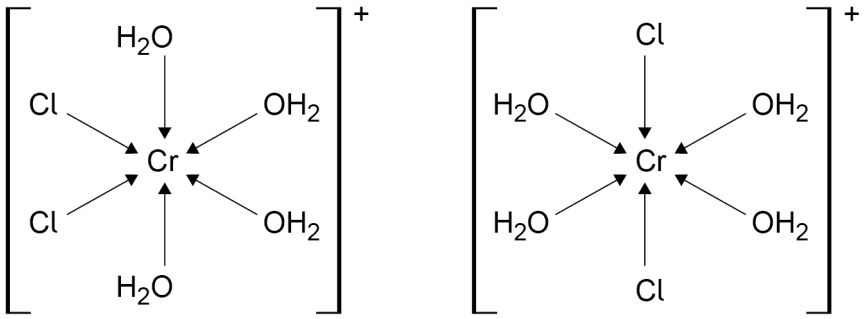
Total		14	

Question	Marking guidance	Mark	Comments
06.1	$(1s^2)\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$	1	
	Cu^+ has a full *d* sub-shell **or** does not have an incomplete *d* sub-shell	1	allow *d* orbitals are full
	no (3)d-(3)d transitions are possible **or** cannot absorb visible light	1	

Question	Marking guidance	Mark	Comments
06.2	$E = h\nu$ **or** $E=hf$	1	
	$\nu\ (= \frac{E}{h} = \frac{3.354 \times 10^{-19}}{6.626 \times 10^{-34}}) = 5.062 \times 10^{14}$	1	must be 2 significant figures or more
	s^{-1}	1	allow Hz

Total		6	

Question	Marking guidance	Mark	Comments
07.1	(central) metal atom/ion surrounded by ligands	1	allow the coordination number exceeds the oxidation state of the metal

Question	Marking guidance	Mark	Comments
07.2		2	allow displayed formulas allow with lines instead of coordinate bonds ignore absence of charge but penalise incorrect charge M1 – cis and trans isomers of $[Cr(H_2O)_4Cl_2]^+$ M2 – correct coordination in both octahedral complexes

Question	Marking guidance	Mark	Comments
07.3	$[Cr(H_2O)_6]^{3+} + 3\,H_2NCH_2CH_2NH_2 \rightarrow [Cr(H_2NCH_2CH_2NH_2)_3]^{3+} + 6\,H_2O$	1	
	increase in number of moles from left to right **or** 4 → 7 (moles)	1	
	increase in disorder	1	

Total		6	

Question	Marking guidance	Mark	Comments
08.1	$[Al(H_2O)_3(OH)_3]$ **and** CO_2	1	both compounds for mark

Question	Marking guidance	Mark	Comments
08.2	acid-base **or** hydrolysis	1	do not accept neutralisation

Question	Marking guidance	Mark	Comments
08.3	sodium hydroxide/NaOH(aq) **or** potassium hydroxide/KOH(aq)	1	
	excess (of NaOH) **or** concentrated (NaOH)	1	
	$[Al(H_2O)_6]^{3+} + 4\,OH^- \rightarrow [Al(OH)_4]^- + 6\,H_2O$	1	allow $[Al(H_2O)_2(OH)_4]^-$

Question	Marking guidance	Mark	Comments
08.4	$[Al(H_2O)_6]^{3+}$	1	
	$[Al(OH)_4]^- + 4\,H^+ + 2\,H_2O \rightarrow [Al(H_2O)_6]^{3+}$	1	

Total		7	

Question	Marking guidance	Mark	Comments
09.1	mean titre = 24.90 (cm^3)	1	
	$n(C_2O_4^-)$ (= $\frac{1.68}{134}$) = 0.0125 (mol)	1	
	$n(C_2O_4^-$ used in titre) (= $0.0125 \times \frac{25}{250}$) = 0.00125 (mol)	1	M3 = M2 ÷ 10
	$n(MnO_4^-)$ (= $0.00125 \times \frac{2}{5}$) = 0.000501 (mol)	1	M4 = M3 × $\frac{2}{5}$
	$[MnO_4^-]$ (= $0.000501 \times \frac{1000}{24.90}$) = 0.0201 (mol dm^{-3})	1	allow $0.000501 \times \frac{1000}{\textbf{M1}}$ if they incorrectly use all 3 titres M1 (= 25.35 cm^3) allow (= $0.000501 \times \frac{1000}{25.35}$) = 0.0198 (mol dm^{-3}) (4)

Question	Marking guidance	Mark	Comments
09.2	the reaction is slow **or** the reaction has a high E_a **or** the reaction is between two negative ions	1	allow to increase the rate of reaction

Question	Marking guidance	Mark	Comments
09.3	the titre value is higher (than the volume of $KMnO_4$ added)	1	

	Marking guidance	Mark	Comments
09.4	so you know when to start adding dropwise **or** accurate titrations need only be dropwise over a small range	1	ignore air bubbles

Question	Marking guidance	Mark	Comments
09.5	colourless to (pale) pink MnO_4^- ions in excess	1 1	both colours needed do **not** accept to purple

Question	Marking guidance	Mark	Comments
09.6	titre values would be higher **or** more MnO_4^- used chlorine (is produced which) is toxic	1 1	 allow poisonous

Total		12	

Question	Marking guidance	Mark	Comments
10.1	heterogeneous	1	
	$SO_2 + V_2O_5 \rightarrow SO_3 + V_2O_4$	1	allow 2 VO_2 instead of V_2O_4
	$½O_2 + V_2O_4 \rightarrow V_2O_5$	1	allow 1 mark for two correct equations but in the wrong order.

Question	Marking guidance	Mark	Comments
10.2	variable oxidation states	1	

Question	Marking guidance	Mark	Comments
10.3	bind to active sites **or** blocks active sites	1	

Question	Marking guidance	Mark	Comments
10.4	maximises/increases the surface area	1	ignore cost

Total		6	