National
Qualifications

X813/77/02

Chemistry

Marking Instructions

Please note that these marking instructions have not been standardised based on candidate responses. You may therefore need to agree within your centre how to consistently mark an item if a candidate response is not covered by the marking instructions.

General marking principles for Advanced Higher Chemistry

Always apply these general principles. Use them in conjunction with the detailed marking instructions, which identify the key features required in candidates' responses.

(a) Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted for errors or omissions.

(b) If a candidate response does not seem to be covered by either the principles or detailed marking instructions, and you are uncertain how to assess it, you must seek guidance from your team leader.

(c) Do not award half marks.

(d) Award full marks for the correct response to a calculation (including units, if appropriate) without working. An exception to this is when candidates are asked to 'Find, by calculation' or 'Clearly show your working for the calculation'.

(e) Ideally, numerical values should be given to the correct number of significant figures as shown in the **detailed marking instructions**. Full marks can be awarded for values that have one significant figure fewer and up to two more significant figures than the expected answer. Exceptions to this rule will be given in the detailed marking instructions. Incorrect significant figures would only be penalised once in any paper and cannot be applied if marking instruction **(h)** has already been applied in the paper.

(f) Where a candidate makes an error at an early stage in a multi-stage calculation, award partial marks, as shown in the **detailed marking instructions**, for correct follow-on working in subsequent stages, unless the error significantly reduces the complexity of the remaining stages. Apply the same principle for questions that require several stages of non-mathematical reasoning. The exception to this rule is where the marking instructions for a numerical question assign separate 'concept marks' and an 'arithmetic mark'. In such situations, the marking instructions will give clear guidance on the assignment of partial marks.

(g) Ideally, calculated intermediate values should not be rounded. If the candidate has correctly rounded, the calculated intermediate values can have one significant figure fewer than the data given in the question but no fewer. **For example**, if the data in the question is given to three significant figures, the intermediate value should have no fewer than two significant figures.

(h) In many questions, the unit in which the answer is to be expressed is given. In these questions, the candidate does not need to state a unit in their answer; but if they do, the unit must be correct. The full mark allocation cannot be awarded if an incorrect unit is shown. In these questions, incorrect units would only be penalised once in any paper and cannot be applied if marking instruction **(e)** has already been applied in the paper.

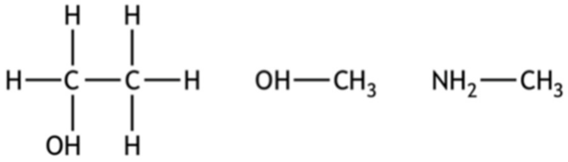
(i) Candidates may fully access larger mark allocations whether their responses are in continuous prose, linked statements, or a series of developed bullet points.

(j) Do not deduct marks for inaccurate or unconventional spelling or vocabulary as long as the meaning of the word(s) is conveyed. **For example**, responses that include 'distilling' for 'distillation', or 'it gets hotter' for 'the temperature rises', are acceptable. Exceptions to this rule will be given in the **detailed marking instructions**.

(k) If a correct response and a wrong response are given, award no marks. **For example**, in response to the question, 'State the colour seen when blue Fehling's solution is warmed with an aldehyde', do not award marks for the response 'red green'. However, if a correct response is followed by additional information which does not conflict with that, ignore the additional information, whether correct or not. **For example**, in response to a question concerned with melting point, 'State why the tube should not be made of copper', the response 'Copper has a low melting point and is coloured grey' **would** gain marks.

(l) Ignore the omission of one H atom from a full structural formula provided the bond is shown. Ignore the omission of one bond provided the attached atom is shown.

If a structural formula is asked for, award marks only if the bond points to the appropriate atom. **For example**, the structural formulae shown below would not be awarded marks



This marking instruction must only be applied a maximum of once per question.

(m) Award marks for a symbol or correct formula in place of a name unless stated otherwise in the **detailed marking instructions**.

(n) When formulae of ionic compounds are given as responses, candidates only need to show ion charges if these have been specifically asked for. However, if ion charges are shown, they must be correct. If incorrect charges are shown, do not award marks.

(o) If an answer comes directly from the text of the question, do not award marks. **For example**, in response to the question, 'A student found that 0·05 mol of propane, burned to give 82·4 kJ of energy. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(\ell)$. Name the kind of enthalpy change that the student measured', do not award marks for 'burning' since the word 'burned' appears in the text.

(p) A guiding principle in marking is to give credit for correct elements of a response rather than to look for reasons not to give marks.

Example 1: If a structural formula is asked for, CH_3 and CH_3CH_2 are acceptable as methyl and ethyl groups respectively unless the question asks for a skeletal structural formula.

Example 2: If a name is asked for such as 3-methylhexane, then 3, methyl-hexane would be acceptable although the use of comma and dashes is not correct.

(q) Unless the question is clearly about a non-chemistry issue, for example costs in an industrial chemical process, do not award marks for a non-chemical response.
For example, in response to the question, 'Why does the (catalytic) converter have a honeycomb structure?', do not award a mark for 'To make it work'. This response may be correct but it is not a chemical response.

(r) Only award marks for a valid response to the question asked. Where candidates are asked to:

- **identify**, **name**, **give** or **state**, they must only name or present in brief form.
- **describe**, they must provide a statement or structure of characteristics and/or features.
- **explain**, they must relate cause and effect and/or make relationships between things clear.
- **compare**, they must demonstrate knowledge and understanding of the similarities and/or differences between things.
- **complete**, they must finish a chemical equation or fill in a table with information.
- **determine** or **calculate**, they must determine a number from given facts, figures or information.
- **draw**, they must draw a diagram or structural formula, for example 'Draw a diagram to show the part of a poly(propene) molecule formed from two propene molecules.'
- **estimate**, they must determine an approximate value for something.
- **predict**, they must suggest what may happen based on available information.
- **evaluate**, they must make a judgement based on criteria.

- **suggest**, they must apply their knowledge and understanding of chemistry to a new situation. A number of responses are acceptable: award marks for any suggestions that are supported by knowledge and understanding of chemistry.
- **use their knowledge of chemistry or aspect of chemistry to comment on**, they must apply their skills, knowledge and understanding to respond appropriately to the problem/situation presented (for example by making a statement of principle(s) involved and/or a relationship or equation, and applying these to respond to the problem/situation). Candidates gain marks for the breadth and/or depth of their conceptual understanding.
- **write**, they must complete a chemical or word equation, for example ‘Write the word equation for the complete combustion of ethanol.’

Marking instructions for each question

Section 1

Question	Answer	Mark
1.	C	**1**
2.	A	**1**
3.	D	**1**
4.	C	**1**
5.	A	**1**
6.	C	**1**
7.	B	**1**
8.	D	**1**
9.	B	**1**
10.	A	**1**
11.	B	**1**
12.	C	**1**
13.	D	**1**
14.	C	**1**
15.	D	**1**
16.	B	**1**
17.	A	**1**
18.	D	**1**
19.	C	**1**
20.	A	**1**
21.	D	**1**
22.	B	**1**
23.	C	**1**
24.	A	**1**
25.	C	**1**

Section 2

Question			Expected response	Max mark	Additional guidance
1.	(a)		(Electrons) drop to lower (energy) levels	**1**	The words in brackets are not required.
	(b)	(i)	620 (nm) **(2)** Partial marking 1 mark may be awarded for one of the following: use of correct equations – $c=f\lambda$ AND $E = Lhf$ **OR** use of $E = \frac{Lhc}{\lambda}$ **OR** use of $\lambda = \frac{Lhc}{E}$ **OR** direct substitution into any of the correct equations above	**2**	Additional acceptable answers are 620·4/620·40 (general marking instruction (e)). As the lowest number of significant figures in the data is 3 the range in the answer can be between 2 and 5 significant figures. If intermediate rounding has taken place when using the $c=f\lambda$ and $E = Lhf$ separately then general marking instruction **(g)** applies. For an intermediate value of 4·84 x 10^{14} for frequency the acceptable answers are: 620/619·8/619·83 For an intermediate value of 4·836 x 10^{14} for frequency the acceptable answers are: 620/620·3/620·35 **There are other acceptable answers and if the answer given is not shown above, then the marker should perform the candidate's calculations to check that the answer is correct and complies with general marking instructions (e) and (g).** Units not required but must be correct if given. General marking instruction **(h)** applies.
		(ii)	Calcium	**1**	Allow follow through from b(i).
	(c)	(i)	(The (total) entropy of a reaction (system) and its surroundings always increases (for a spontaneous process)	**1**	The words in brackets are not required.

Question			Expected response	Max mark	Additional guidance
1.	(c)	(ii)	490 (K) **(2)** Partial marking 1 mark may be awarded for one of the following: Use of $\Delta G = \Delta H - T\Delta S$ **OR** Use of $T = \frac{\Delta H}{\Delta S}$ **OR** correct substitution of values directly into the above equations. **OR** reaction is feasible when $\Delta G = 0$	**2**	Additional acceptable answers are 500/491/491·2 (general marking instruction **(e)**). As the lowest number of significant figures in the data is 2 the range in the answer can be between 1 and 4 significant figures. Units not required but must be correct if given. General marking instruction **(h)** applies.

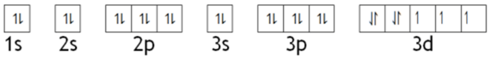
Question			Expected response	Max mark	Additional guidance
2.	(a)		Octahedral	**1**	
	(b)		7	**1**	
	(c)	(i)	Amminepentaaquanickel(II) **OR** monoamminepentaaquanickel(II)	**1**	The name of the complex ion must be spelled exactly as shown.
		(ii)	Forms only one bond (to the metal) **OR** donates/shares one (lone/non-bonding) pair of electrons	**1**	The words in brackets are not required.
	(d)	(i)	2/2nd/second	**1**	Two is not an acceptable answer.
		(ii)	5200 **(1)** $l\ mol^{-1}\ s^{-1}$ **(1)**	**2**	The units can be in any order.

Question			Expected response	Max mark	Additional guidance
3.	(a)	(i)	sp^2	**1**	The number 2 does not need to be superscripted but must come after the 'sp'.
		(ii)	Side-on overlap of (parallel atomic/p) orbitals (that lie perpendicular to the axis of the covalent bond)	**1**	The words in brackets are not required. The mention of overlap of molecular orbitals is not acceptable. No mark is awarded if any mention or drawing of s orbitals
		(iii)	Short conjugated system **OR** few atoms in the conjugated system **OR** delocalised electrons over a small number of carbon atoms **OR** molecular orbital over a small number of carbon atoms **(1)** **AND** A large amount of energy is required to promote an electron from HOMO to LUMO **OR** Large energy gap between HOMO and LUMO **OR** the energy gap between HOMO and LUMO is not small enough to absorb visible light **(1)**	**2**	
	(b)	(i)	(electrophilic) substitution	**1**	The words in brackets are not required. Nucleophilic substitution is awarded zero marks
		(ii)	C_9H_{12}	**1**	
		(iii)	More stable carbocation formed **OR** Secondary carbocation is more stable than primary carbocation	**1**	

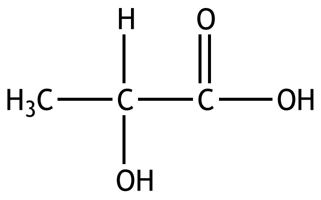
Question			Expected response	Max mark	Additional guidance
4.	(a)		Calcium carbonate/limestone is insoluble.	**1**	
	(b)	(i)	Moles of HCl = 0·0253 **(2)** Partial marking 1 mark may be awarded for one of the following: calculating moles of NaOH in the 10·15 cm^3 average titre volume ($3·045 \times 10^{-3}$ moles) **OR** correctly multiplying an incorrectly calculated moles of NaOH in titre volume or moles of unreacted HCl in the sample by 4 **OR** correctly subtracting a calculated number of moles of HCl, left unreacted in the volumetric flask, from the number of moles of HCl at the start **(1)**	**2**	Additional acceptable answers are 0·025/0·02532 (general marking instruction **(e)**). As the lowest number of significant figures in the data is 3 the range in the answer can be between 2 and 5 significant figures. If intermediate rounding has taken place then general marking instruction **(e)** applies.

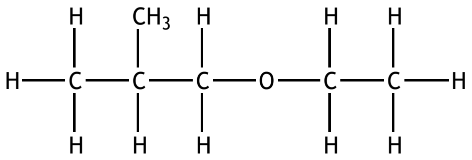
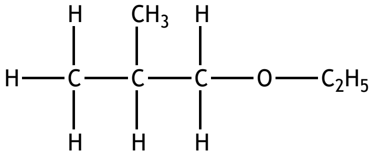
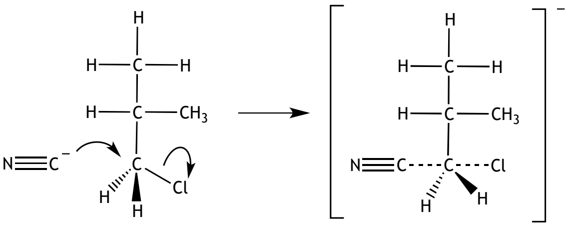
Question			Expected response	Max mark	Additional guidance
4.	(b)	(ii)	97·4% and yes **(2)** Partial marking 1 mark may be awarded for one of the following: applying the 2:1 mole ratio to determine the moles of calcium carbonate present. **OR** correctly calculating a mass of calcium carbonate from an incorrect number of moles **OR** correctly calculating a percentage $CaCO_3$ from an incorrect mass	**2**	Additional acceptable answers are 97/97·41/97·405 (general marking instruction **(e)**). As the lowest number of significant figures in the data is 3 the range in the answer can be between 2 and 5 significant figures. A correct numerical answer and yes, with no working, would be awarded 2 marks. If intermediate rounding has taken place then general marking instruction **(g)** applies. If the mass of $CaCO_3$ is rounded to 1·27 g then the acceptable answers are 97/97·7/97·69/97·692 Allow follow through from (b)(i). If the candidate uses the answer 0·02532 from (b)(i) then the acceptable answers are 97/97·5/97·48/97·482 **There are other acceptable answers and if the answer given is not shown above, then the marker should perform the candidate's calculations to check that the answer is correct and complies with general marking instructions (e) and (g).** A maximum of 1 mark should be awarded if the candidate has not correctly indicated whether the limestone is suitable from their own calculated results.

Question			Expected response	Max mark	Additional guidance
4.	(c)		**Award 3 marks** where the candidate has demonstrated, at an appropriate level, a good understanding of the chemistry involved. They show a good comprehension of the chemistry of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated, at an appropriate level, a reasonable understanding of the chemistry involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated, at an appropriate level, a limited understanding of the chemistry involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the chemistry within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the chemistry involved. There is no evidence that they have recognised the area of chemistry involved, or they have not given any statement of a relevant chemistry principle. Award this mark also if the candidate merely restates the chemistry given in the question.	**3**	Candidates may use a variety of chemistry arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

Question			Expected response	Max mark	Additional guidance
5.	(a)	(i)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7$ **OR** 	**1**	Non-superscripted numbers are acceptable. All of the orbital boxes opposite must be shown and clearly labelled. Single or double headed arrows are acceptable. Accept diagrams showing an empty 4s orbital box.
		(ii)	2+/+2	**1**	Number can be in words/numerals but must include the charge/sign.
	(b)	(i)	Heating substance **(1)** **All three** of the following are required for 1 mark: Cool/leave in a desiccator (to prevent absorption of water) **AND** Weigh **AND** Repeat (the steps of heating, cooling and weighing) to constant mass **(1)**	**2**	The words in brackets are not required.
		(ii)	6 **(2)** Partial marking 1 mark may be awarded for one of the following: Correctly calculating moles of H_2O (0·00933) **AND** moles of $CoCl_2$ (0·00157) **OR** correctly calculating the GFM of $CoCl_2 \cdot nH_2O$ (0·372/0·00157 = 236·9) **AND** correctly calculating the mass of water by subtracting the GFM of $CoCl_2$ (236·9-129·9 = 107) **OR** correctly calculating a value for *n* using incorrect moles of $CoCl_2$ or H_2O **OR** correctly calculating a value for n using incorrect GFM for $CoCl_2 \cdot nH_2O$ or $CoCl_2$.	**2**	General marking instruction **(e) does not** apply as the answer given must be a whole number. An answer of 6 with no working would be awarded **zero marks**. If intermediate rounding has taken place then general marking instruction **(g)** applies.

Question			Expected response	Max mark	Additional guidance
5.	(c)	(i)	EDTA	**1**	
		(ii)	Colorimetry **OR** Spectrophotometry **OR** Atomic emission/absorption spectroscopy **OR** Precipitation	**1**	

Question			Expected response	Max mark	Additional guidance
6.	(a)		The candidate answer must show that they have correctly worked out the number of moles of each element: 3·33 C; 6·70 H; 3·33 O	**1**	
	(b)	(i)	$C_3H_6O_3$	**1**	The elements can be in any order.
		(ii)	$[COOH]^+$ / $[CO_2H]^+$ **OR** ^+COOH / $^+CO_2H$ **OR** $[CH_3CHOH]^+$ / $[C_2H_5O]^+$ **OR** CH_3C^+HOH / $^+C_2H_5O$ **OR** $[CH_3CH_2O]^+$ **OR** $CH_3CH_2O^+$ / $C_2H_5O^+$	**1**	Positive charge must be present. The positive charge must **not** be on a hydrogen atom, for example, $COOH^+$ Round brackets are also acceptable.
	(c)		 **OR** $CH_3CH(OH)COOH$ **OR** any other correct structural formula	**1**	Markers should check that the connectivity of the atoms is correct – general marking instruction **(l)**.

Question			Expected response	Max mark	Additional guidance
7.	(a)		 **OR**  **OR** any other correctly drawn structural formula	**1**	Markers should check that the connectivity of the atoms is correct - general marking instruction **(l)**.
	(b)		Carboxylic acids	**1**	
	(c)		Two correct curly arrows (1)  Transition state (1)	**2**	Double arrow heads are required for both curly arrows. The curly arrow from the nucleophile must come from the carbon and point to the space between this carbon and the correct carbon in the haloalkane. The other curly arrow must start from the middle of the C — Cl bond and point towards the chlorine atom. Transition state must be inside brackets with a negative charge outside of the brackets. Markers should check that the connectivity of all of the atoms is correct in the transition state structure - general marking instruction **(l)** applies.
	(d)	(i)	Ethanol/alcohol	**1**	

Question			Expected response	Max mark	Additional guidance
7.	(d)	(ii)	278 cm^3/0·278 l **(3)** Partial marking 1 mark may be awarded for the correct unit for a calculated final volume. **(1)** 1 mark may also be awarded for one of the following: Correctly calculating the theoretical yield of methylpropene - 460 (cm^3) / 0·46 (l) / 1·12 (g) **OR** correctly calculating 60.4% of an incorrect theoretical yield **OR** correctly calculating 60·4% of 0·02 moles (theoretical) methylpropene (0·01208 moles). **OR** correctly multiplying an incorrect moles (actual) methylpropene by 23.	**3**	Correct units are required in this question. L is also an acceptable abbreviation for litres. Additional acceptable answers are: 280/277·8/277·84 (cm^3) **OR** 0·28/0·2778/0·27784 (l) (general marking instruction **(e)**). As the lowest number of significant figures in the data is 3 the range in the answer can be between 2 and 5 significant figures. General marking instruction **(g)** applies to the calculation and so alternative answers are shown below: If 0·0121 moles of methylpropene is used then the acceptable answers are: 280/278/278·3 (cm^3) **OR** 0·28/0·278/0·2783 (l) If 0·012 moles of methylpropene is used then the acceptable answers are: 280/276 (cm^3) **OR** 0.28/0.276 (l) 0·02 is an acceptable number of moles of methylpropene rather than 0·0200 in this question. **There are other acceptable answers and if the answer given is not shown above, then the marker should perform the candidate's calculations to check that the answer is correct and complies with general marking instructions (e) and (g).**

Question			Expected response	Max mark	Additional guidance
8.	(a)		CH_3COO^- **OR** any correct structural formula	**1**	Negative charge must be present on the O.
	(b)	(i)	4·36 **(3)** Partial marking 1 mark may be awarded for: correctly calculating concentration of sodium ethanoate = 0·200 (mol l^{-1}) 1 mark may also be awarded for one of the following: $pH = pK_a - \log_{10}\frac{[\text{acid}]}{[\text{salt}]}$ **OR** direct substitution of values into $pH = pK_a - \log_{10}\frac{[\text{acid}]}{[\text{salt}]}$	**3**	Additional acceptable answers are: 4·4/4·362/4·3621 (general marking instruction **(e)**). As the lowest number of significant figures in the data is 3 the range in the answer can be between 2 and 5 significant figures. The volume of the 250 cm^3 of buffer solution is taken as being to 3 significant figures since it would have been made up in a standard flask. General marking instruction **(g)** applies to this calculation. However, 0·2 (mol l^{-1}) is acceptable for the concentration of sodium ethanoate rather than 0·200. **There are other acceptable answers and if the answer given is not shown above, then the marker should perform the candidate's calculations to check that the answer is correct and complies with general marking instructions (e) and (g).** **Award 2 marks** for correctly calculating a pH from an incorrect sodium ethanoate concentration**.**
		(ii)	The concentration of the acid and salt will change by the same amount **OR** the acid and the salt are diluted by the same amount **OR** (the concentration) ratio of the acid and salt is unchanged	**1**	The words in brackets are not required.

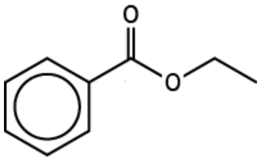
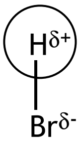
Question			Expected response	Max mark	Additional guidance
	(c)		Use the same volume of each buffer solution **(1)** Then, measure the (rise/change in) pH after the same volume/moles of alkali has been added **OR** the solution which shows the smallest change in pH when the same volume/moles of alkali has been added has the larger buffer capacity **OR** measure the volume of alkali required to raise the pH by the same value/from pH5 to 6. **(1)**	**2**	Candidates may mention specific quantities in their experimental procedure and as long as they fit with the general procedures opposite then the marks should be awarded. The words in brackets are not required. Other specific pH changes are acceptable as long they are from pH5 to a higher value and it's clear the same pH change is used for both buffers.

Question			Expected response	Max mark	Additional guidance
9.	(a)		(A substance that) alters the biochemical processes in the body.	**1**	The words in brackets are not required.
	(b)		Inhibitor	**1**	
	(c)		2500 (ppm)	**1**	Additional acceptable answers are: 2000/2480/2483 (general marking instruction **(e)**). As the lowest number of significant figures in the data is 2 the range in the answer can be between 1 and 4 significant figures. If intermediate rounding has taken place then general marking instruction **(g)** applies. If mass of methotrexate in the dose is rounded to 5·7 mg then the acceptable answers are: 2000/2500/2480/2478 Units not required but must be correct if given. General marking instruction **(h)** applies.

Question			Expected response	Max mark	Additional guidance
	(d)		**Award 3 marks** where the candidate has demonstrated, at an appropriate level, a good understanding of the chemistry involved. They show a good comprehension of the chemistry of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated, at an appropriate level, a reasonable understanding of the chemistry involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated, at an appropriate level, a limited understanding of the chemistry involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the chemistry within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the chemistry involved. There is no evidence that they have recognised the area of chemistry involved, or they have not given any statement of a relevant chemistry principle. Award this mark also if the candidate merely restates the chemistry given in the question.	**3**	Candidates may use a variety of chemistry arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

Question			Expected response	Max mark	Additional guidance
10.	(a)	(i)	58·1 (g) Partial marking 1 mark may be awarded for: correctly calculating the value for n = 0·00892 **OR** correctly calculating a GFM using an incorrect value for n **(1)**	**2**	Additional acceptable answers are: 58/58·09/58·088 (general marking instruction **(e)**). As the lowest number of significant figures in the data is 3 the range in the answer can be between 2 and 5 significant figures. A correct answer with no working is worth 2 marks. If intermediate rounding has taken place then general marking instruction **(g)** applies. If the value for n used is 0·0089 then the acceptable answers are: 58/58·2/58·20/58·202 If the value for n used is 0·00892 then the acceptable answers are: 58/58·1/58·07/58·072 If the value for n used is 0·008918 then the acceptable answers are: 58/58·1/58·08/58·085 Units not required but must be correct if given. General marking instruction **(h)** applies.
		(ii)	Propanone/propanal **OR** C_2H_6O **OR** a correct structural formula for propanone/propanal **OR** any other carbonyl compound that fits the GFM calculated in (a)(i).	**1**	
	(b)		The boiling point (of butanoic acid) is above 100 °C/the boiling point of water **OR** the water (bath) cannot reach a high enough temperature.	**1**	The words in brackets are not required.

Question			Expected response	Max mark	Additional guidance
11.	(a)	(i)	$K = \frac{\left[I_3^-(aq)\right]}{\left[I_2(aq)\right]\left[I^-(aq)\right]}$ **OR** $K = \frac{\left[I_3^-\right]}{\left[I_2\right]\left[I^-\right]}$	**1**	State symbols are not required but any that are given must be correct. Ion charges must be shown. Square brackets must be used.
		(ii)	779 Partial marking 1 mark may be awarded for one of the following: calculating the equilibrium concentration of I^- = 0·123 (mol l^{-1}) **OR** correctly calculating a value for *K* using an incorrect concentration for one of the species.	**2**	Additional acceptable answers are: 780/779·4/779·41 (general marking instruction **(e)**). As the lowest number of significant figures in the data is 3 the range in the answer can be between 2 and 5 significant figures. If intermediate rounding has taken place then general marking instruction **(g)** applies. If the candidate incorrectly uses 0·239 mol l^{-1} for the concentration of I^-, the acceptable values for **1 mark** are: 401/401·1/401·12 There are no units for an equilibrium constant. Therefore, if any units are given they will be incorrect and general marking instruction **(h)** applies.
	(b)		Structure depends on VSEPR/ minimising repulsion/minimising repulsion between lone/non-bonding pairs **OR** repulsion is greatest between lone/non-bonding pairs (1) (In B) the lone/non-bonding pairs are 120^o from one another **OR** in A the lone/non-bonding pairs are 90^o from one another **OR** the angle is greater between lone/non-bonding pairs (in B) **OR** the lone/non-bonding pairs are further away from each other (in B) **(1)**	**2**	

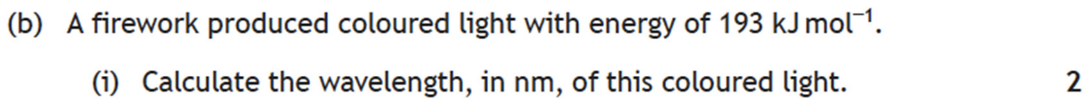
Question			Expected response	Max mark	Additional guidance
12.	(a)			**1**	
	(b)		To prevent reactant/product/vapour from escaping **OR** to allow prolonged heating	**1**	
	(c)		Distillation	**1**	
	(d)		Elimination	**1**	
	(e)		(Slightly) positively charged hydrogen (in HBr) **OR**  $H^{\delta+}-Br^{\delta-}$	**1**	The words in brackets are not required.
	(f)	(i)	The (benzoate) ion from the salt removes/reacts with H^+ from the water **OR** the conjugate base of the weak acid, removes/reacts with H^+ ions from the water **(1)** This results in the water equilibrium shifting to the right hand side **OR** shifting to the left hand side if candidate has written an equilibrium reaction with ions on the left hand side **OR** this results in excess OH^- ions from the water equilibrium. **(1)**	**2**	The words in brackets are not required. Zero marks are awarded for “It is the salt of a strong base and a weak acid” without further explanation.
		(ii)	Filtration	**1**	
	(g)		Recrystallisation	**1**	

Question			Expected response	Max mark	Additional guidance
12.	(h)	(i)	Pure benzoic acid	**1**	
		(ii)	Any mention of measuring or looking up the melting point of pure benzoic acid **(1)** Correctly linking the mixed melting point value to the purity **(1)**	**2**	The statement "The sample is pure if the mixed melting point is the same as pure benzoic acid," would be awarded **2 marks**. The statement, "The sample is impure if the mixed melting point is lower than pure benzoic acid," would also be awarded **2 marks.**
	(i)		Spectrum C No C=O peak at 1700 cm^{-1} in spectrum C **OR** spectra A and B have a C=O peak at 1700 cm^{-1}. (1)	**2**	

[END OF MARKING INSTRUCTIONS]

Exemplification of Marking Instructions

Question 1(b)(i)



(b) A firework produced coloured light with energy of 193 kJ mol^{-1}.

(i) Calculate the wavelength, in nm, of this coloured light. 2

Example 1

$$E = \frac{Lhf}{1000}$$

$$f = \frac{1000E}{Lh} = \frac{193000}{Lh}$$

$$= 4.84 \times 10^{14}$$

$$\lambda = \frac{c}{f}$$

$$= \frac{c}{4.84 \times 10^{14}} = 619.8$$

2 marks

There is intermediate rounding of the value for frequency, and this value is given to 3 significant figures. General marking instruction **(g)** applies. The data is also to 3 significant figures and so this rounding is acceptable (a minimum of 2 significant figures would be allowed.)

Example 2

$$E = Lhf$$

$$f = \frac{E}{Lh} = \frac{193}{6.02 \times 10^{23} \times 6.63 \times 10^{-34}}$$

$$= 4.8356 \times 10^{11}$$

$$c = f\lambda$$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^{8}}{4.8356 \times 10^{11}}$$

$$= 620403$$

1 mark

The candidate has not multiplied by 1000 when calculating the frequency.
1 mark is awarded for stating E = Lhf and c = fλ.

Example 3

$$E = \frac{Lhf}{1000}$$

$$f = \frac{1000\,E}{Lh} = \frac{1000 \times 193}{6.02\times10^{23} \times 6.63\times10^{-34}}$$

$$= 4.83 \times 10^{14}$$

$$c = f\lambda$$

$$\lambda = \frac{c}{f} = \frac{3\times10^{8}}{4.83\times10^{14}} = 621$$

1 mark

The candidate has incorrectly rounded the value for f (should be 4·84 x 10^{14}) and so the final answer is not correct. 1 mark is awarded for stating E = Lhf(/1000) and c = fλ

Example 4

$$E = \frac{Lhc}{1000\lambda}$$

$$\lambda = \frac{Lhc}{1000\,E} = \frac{6.02\times10^{23} \times 6.63\times10^{-34} \times 3\times10^{8}}{1000 \times 193}$$

$$= 620.403$$

1 mark

The candidate has calculated a correct final value. However, that value is quoted to 6 significant figures, which is out with the acceptable range. General marking instruction **(e)** applies. 1 mark is deducted assuming that this is the first time the significant figures rule or the units rule has been applied in the paper.

Example 5

$$193 = \frac{Lhf}{1000}$$

$$f = \frac{193000}{Lh} = 4.836 \times 10^{14}$$

$$\lambda = \frac{c}{4.836\times10^{14}} = 0.000620$$

1 mark

The candidate has not correctly converted the final answer into nanometres.
1 mark is awarded for direct substitution into E = Lhf and c = fλ.

Question 1(c)(ii)

(c) Fireworks also contain potassium nitrate, which decomposes when heated to produce oxygen.

$$2KNO_3(s) \rightarrow 2KNO_2(s) + O_2(g) \qquad \Delta H^\circ = +250\ \text{kJ mol}^{-1}$$

$$\Delta S^\circ = +509\ \text{J K}^{-1}\,\text{mol}^{-1}$$

(ii) Calculate the temperature, in K, above which this reaction becomes feasible. **2**

Example 1

$$\Delta G = \Delta H - T\Delta S$$

$$T = \frac{\Delta G - \Delta H}{\Delta S} = \frac{0 - 250}{0.509}$$

$$= -491\ K$$

1 mark

The candidate has not correctly rearranged ΔG = ΔH-TΔS and has ended up with a negative value for the temperature. 1 mark is awarded for stating ΔG = ΔH-TΔS.

Example 2

$$\Delta G = \Delta H - T\Delta S$$

Feasible when $\Delta G = 0$

$$T = \frac{\Delta H}{\Delta S} = \frac{250}{0.509} = 491\ k$$

1 mark

The candidate has stated a correct numerical answer. Although the unit does not need to be given, the candidate has given an incorrect one (should be K not k). General making instruction **(h)** applies. 1 mark is deducted assuming that this is the first time the units rule or the significant figures rule has been applied in the paper.

Example 3

$$0 = 250 - (509 \times T)$$

$$T = \frac{250}{509} = 0.49$$

1 mark

The candidate has not divided the value for ΔS by 1000 and therefore the answer given is not correct. 1 mark is awarded for either direct substitution into ΔG = ΔH-TΔS or for realising that ΔG = 0.

Example 4

$$\Delta G = 0$$

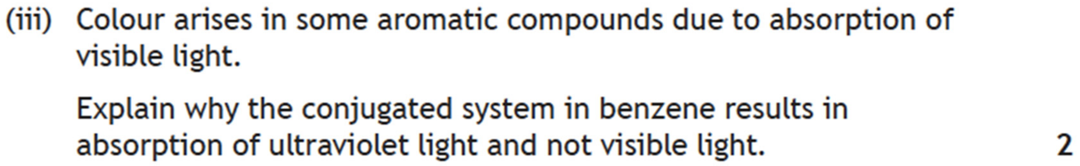
$$T = \frac{\Delta S}{\Delta H} = \frac{509}{250}$$

$$= 2.04$$

1 mark

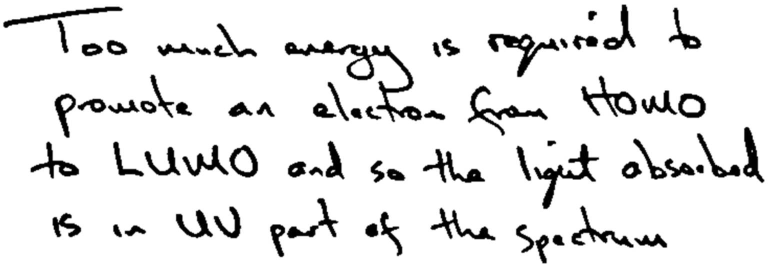
The candidate has rearranged ΔG = ΔH-TΔS incorrectly and also has not divided the ΔS value by 1000. The answer given is, therefore, incorrect. 1 mark is awarded for stating that ΔG = 0.

Question 3(a)(iii)


(iii) Colour arises in some aromatic compounds due to absorption of visible light.

Explain why the conjugated system in benzene results in absorption of ultraviolet light and not visible light. 2

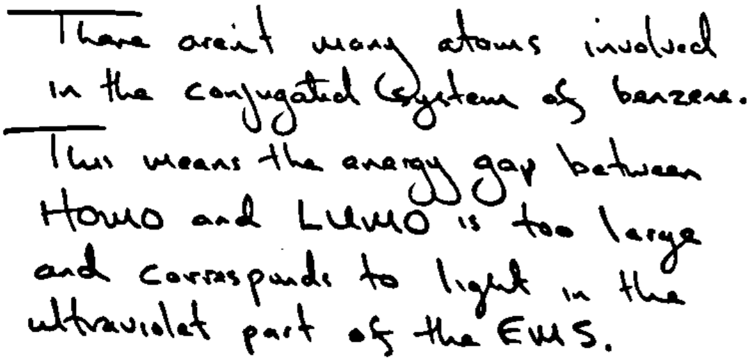
Example 1


Too much energy is required to promote an electron from HOMO to LUMO and so the light absorbed is in UV part of the spectrum

1 mark

The first mark cannot be awarded since there is no mention of the size of the conjugated system. The second mark is awarded for implying that a lot of energy (‘too much energy’) is required to promote an electron from HOMO to LUMO.

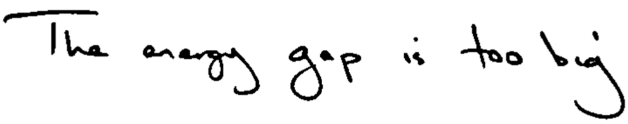
Example 2


There aren't many atoms involved in the conjugated system of benzene. This means the energy gap between HOMO and LUMO is too large and corresponds to light in the ultraviolet part of the EMS.

2 marks

The first mark is awarded for a ‘there aren’t many atoms involved in the conjugated system’ which suggests that there are few or the conjugated system is small.
The second mark is awarded for the ‘energy gap between HOMO and LUMO is too large’.

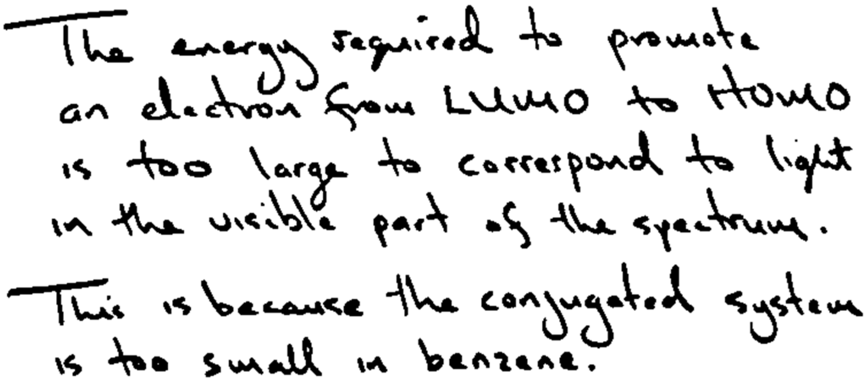
Example 3


The energy gap is too big

0 marks

The first mark cannot be awarded since there is no mention of the size of the conjugated system.
The second mark cannot be awarded since there is no mention of what the energy gap is between.

Example 4



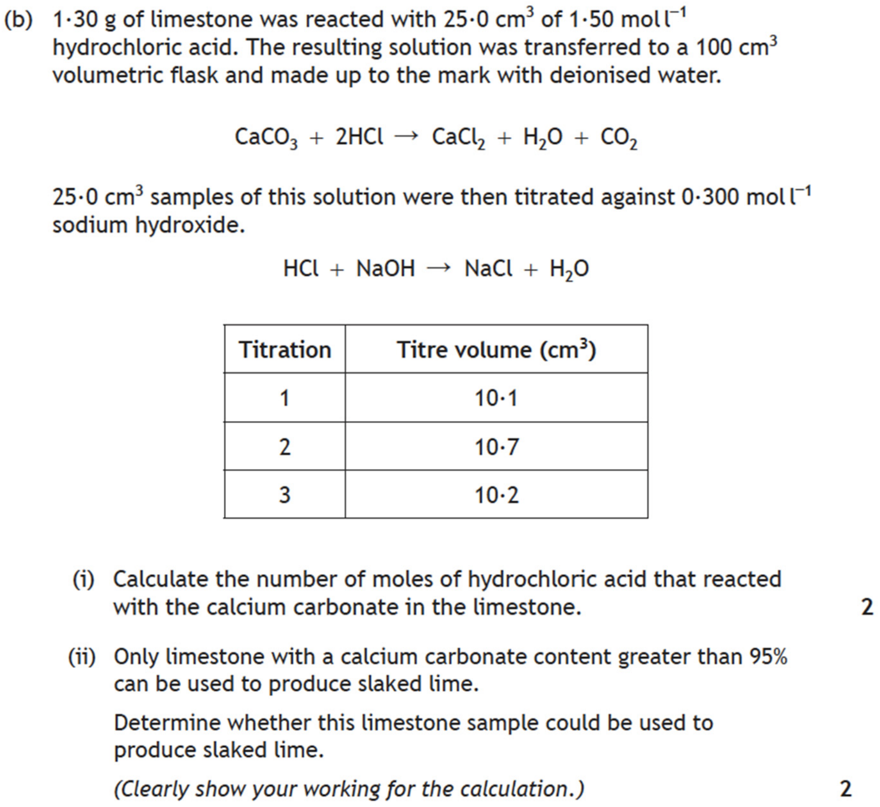
The energy required to promote an electron from LUMO to HOMO is too large to correspond to light in the visible part of the spectrum.

This is because the conjugated system is too small in benzene.

1 mark

The first mark is awarded for ‘the conjugated system is too small.’
The second mark cannot be awarded since, although, the candidate states a large amount of energy is required, the rest of the statement is incorrect, - ‘promote an electron from LUMO to HOMO.’

Question 4(b) (comprising parts (i) and (ii) with follow through)



(b) 1·30 g of limestone was reacted with 25·0 cm^3 of 1·50 mol l^{-1} hydrochloric acid. The resulting solution was transferred to a 100 cm^3 volumetric flask and made up to the mark with deionised water.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

25·0 cm^3 samples of this solution were then titrated against 0·300 mol l^{-1} sodium hydroxide.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Titration	Titre volume (cm^3)
1	10·1
2	10·7
3	10·2

(i) Calculate the number of moles of hydrochloric acid that reacted with the calcium carbonate in the limestone. 2

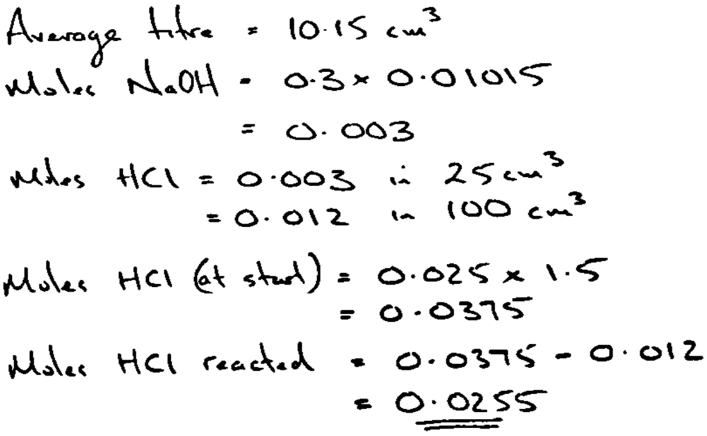
(ii) Only limestone with a calcium carbonate content greater than 95% can be used to produce slaked lime.

Determine whether this limestone sample could be used to produce slaked lime.

(Clearly show your working for the calculation.) 2

Example 1

Part (i)



Average titre = 10·15 cm^3

Moles NaOH = 0·3 × 0·01015

= 0·003

Moles HCl = 0·003 in 25 cm^3

= 0·012 in 100 cm^3

Moles HCl (at start) = 0·025 × 1·5

= 0·0375

Moles HCl reacted = 0·0375 − 0·012

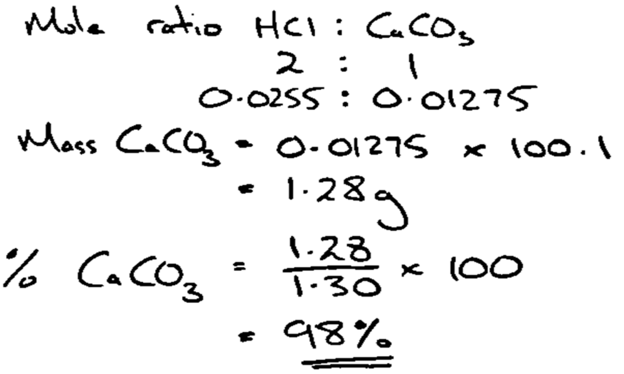
= 0·0255

1 mark

The final answer is not acceptable since there was inappropriate rounding of the moles of NaOH in the titre. The minimum number of significant figures allowed is 2. General marking instruction **(g)** applies.

1 mark is awarded for either:
correctly multiplying moles of HCl by 4
OR
correct subtraction of unreacted moles of HCl

Part (ii)



Mole ratio HCl : $CaCO_3$

2 : 1

0·0255 : 0·01275

Mass $CaCO_3$ = 0·01275 × 100·1

= 1·28g

% $CaCO_3$ = $\frac{1·28}{1·30}$ × 100

= 98%

1 mark

Follow through is allowed from part (i).

The candidate has correctly calculated a final percentage for the limestone based on their value in part (i). However, they have not indicated whether this limestone could be used to produce slaked lime and so a maximum of 1 mark is awarded.

Example 2

Part (i)

Moles NaOH = 0·3 × 0·01015
= 0·003045
Moles HCl = 0·003045 (unreacted)
Moles HCl at start = 0·0375
Moles HCl reacted = 0·0375 − 0·003045
= $\underline{\underline{0{\cdot}0345}}$

1 mark

The candidate has not multiplied the moles of NaOH by 4 and so the final answer is not correct.

1 mark is awarded for either:
correctly calculating mole of NaOH in titre
OR
correct subtraction of unreacted moles of HCl from moles at start.

Part (ii)

Moles HCl = 0·0345
Moles $CaCO_3$ = 0·01725
Mass $CaCO_3$ = 100·1 × 0·01725
= $\underline{1{\cdot}73}$ g
% $CaCO_3$ = $\frac{1{\cdot}73}{1{\cdot}3}$ × 100 = 133%
This is above 95% so yes

2 marks

Follow through from the previous questions is allowed. Despite the impossible percentage, the candidate has correctly performed this part of the calculation and given an answer to an appropriate number of significant figures. The candidate has also given an appropriate determination and so full marks are awarded.

Example 3

Part (i)

NaOH = 0·3 × 0·01033
= 0·0031 in 25cm³
= 0·0124 in 100cm³
NaOH : HCl = 1:1 ⇒ HCl = 0·0124
Moles HCl reacted = 0·0375 − 0·0124
= $\underline{\underline{0{\cdot}025}}$

1 mark

Although, 0·025 is an acceptable answer, the candidate has not arrived at it by using the correct value for the average titre volume. Therefore full marks cannot be awarded.

1 mark is awarded for either:
multiplying moles of NaOH by 4
OR
correct subtraction of unreacted moles of HCl from moles at start.

Part (ii)

HCl : $CaCO_3$ = 2:1
⇒ n$CaCO_3$ = 0·01255
Mass $CaCO_3$ = 0·01255 × 100·1
= 1·256g
% $CaCO_3$ = $\frac{1{\cdot}256}{1{\cdot}3}$ × 100 = $\underline{\underline{97\%}}$
⇒ Yes

2 marks

The candidate has used the unrounded value from the previous question and performed this part of the calculation correctly to give an acceptable answer.

Example 4

Part(i)

$n\,NaOH = 0.3 \times 10.15$

$= 3.045$ in $25\,cm^3$

$= 12.18$ in $100\,cm^3$

$n\,HCl = \underline{\underline{12.18}}$ (1:1 ratio)

1 mark

The candidate has not changed cm^3 into litres before calculating the number of moles. The subtraction has not been carried out.

1 mark is awarded for correctly multiplying an incorrect number of moles of NaOH by 4.

Part (ii)

$HCl : CaCO_3 = 12.18 : 6.09$

$GFM\ CaCO_3 = 100.1$

$Mass\ CaCO_3 = 100.1 \times 6.09$

$= 609.6\,g$

$\%\ CaCO_3 = \cancel{\frac{609.6}{1.3} \times 100 = 46{,}89}$

$= \frac{1.3}{609.6} \times 100 = 0.213\% \Rightarrow$ No

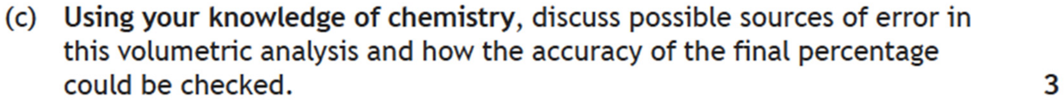
1 mark

Follow through from the previous question is allowed. However, the candidate has not performed the percentage calculation correctly.

1 mark is awarded for either:
correctly applying the 2:1 mole ratio
OR
correctly calculating a mass of $CaCO_3$ from moles.

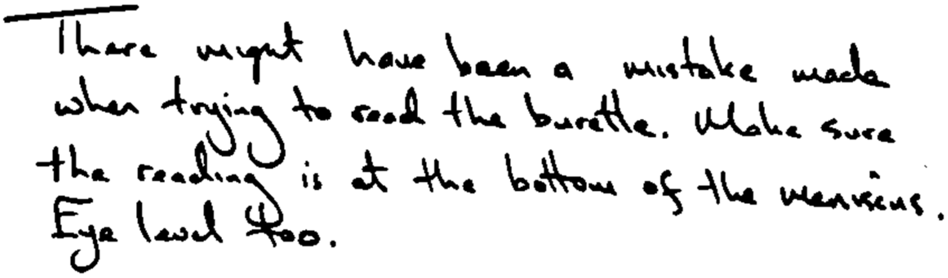
Question 4(c) – Open-ended Question

Remember, open-ended questions are marked holistically according to whether the candidate has provided a good, reasonable or limited response to the problem at Advanced Higher level. Zero marks can be awarded if the response is not related to the problem or not at an appropriate level.



(c) **Using your knowledge of chemistry**, discuss possible sources of error in this volumetric analysis and how the accuracy of the final percentage could be checked. 3

Example 1

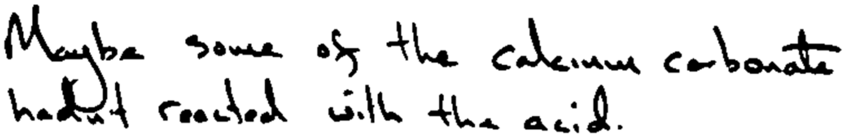


There might have been a mistake made when trying to read the burette. Make sure the reading is at the bottom of the meniscus. Eye level too.

0 marks

This is the level of response that may be expected from a National 5 candidate. This is not the type of error the question is alluding to. There is no response to the question at an appropriate level.

Example 2

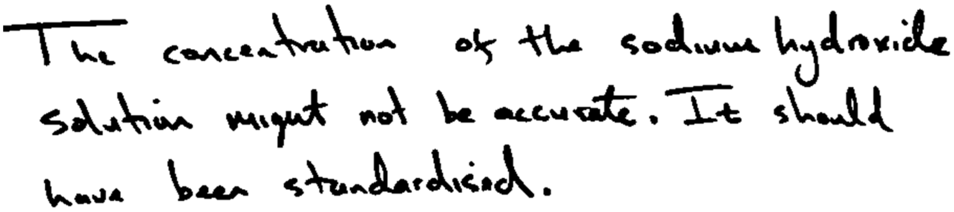


Maybe some of the calcium carbonate hadn't reacted with the acid.

0 marks

Again, this is the level of response that may be expected from a National 5 candidate and not an appropriate level for Advanced Higher.

Example 3



The concentration of the sodium hydroxide solution might not be accurate. It should have been standardised.

1 mark

The candidate has shown a limited understanding of the problem at Advanced Higher level by making a statement that the NaOH solution should have been standardised.

Example 4

The accuracy of the results could improved by repeating the experiment and taking an average. Also make sure that there is a white tile under the flask so that the colour change is clear. Swirl the flask a few times and add the solution drop by drop and not big squirts. You could standardise the solutions too.

1 mark

Although, the steps outlined by the candidate do make for good practice, they do not address the problem at an appropriate level and would not be given credit. However, the candidate does show a limited understanding by stating that the solutions could be standardised.

Example 5

The standard flask, burette and pipette used in the titration don't measure volumes exactly. There is some uncertainty value associated with each. For example a burette reading is only accurate to ±0.1 cm^3. This could make a difference to the result. One thing you could do is use class A apparatus instead of class B.

1 mark

The candidate given a limited response to the problem by stated a source of error in the analysis and given a way of making the error smaller.

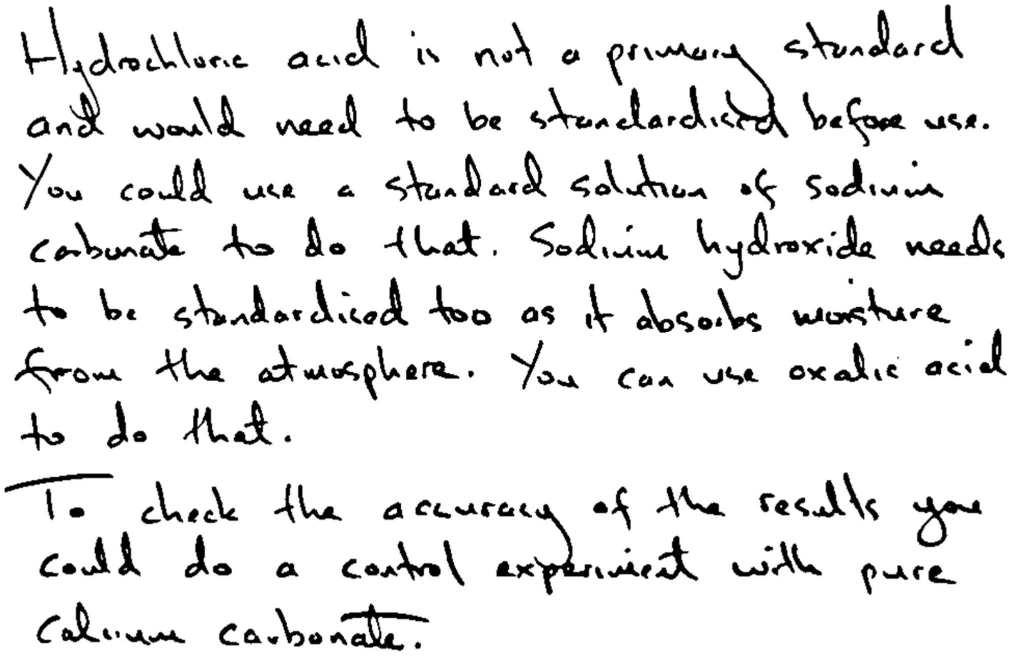
Example 6

Sodium hydroxide is not a primary standard. A primary standard must be soluble, available in high purity and not react with the solvent. Sodium hydroxide absorbs moisture so when it is weighed out some of the mass will be water. The concentration will not be accurate.

2 marks

The candidate has stated a source of error and how that error comes about. Overall, this demonstrates a reasonable understanding at an appropriate level.

Example 7



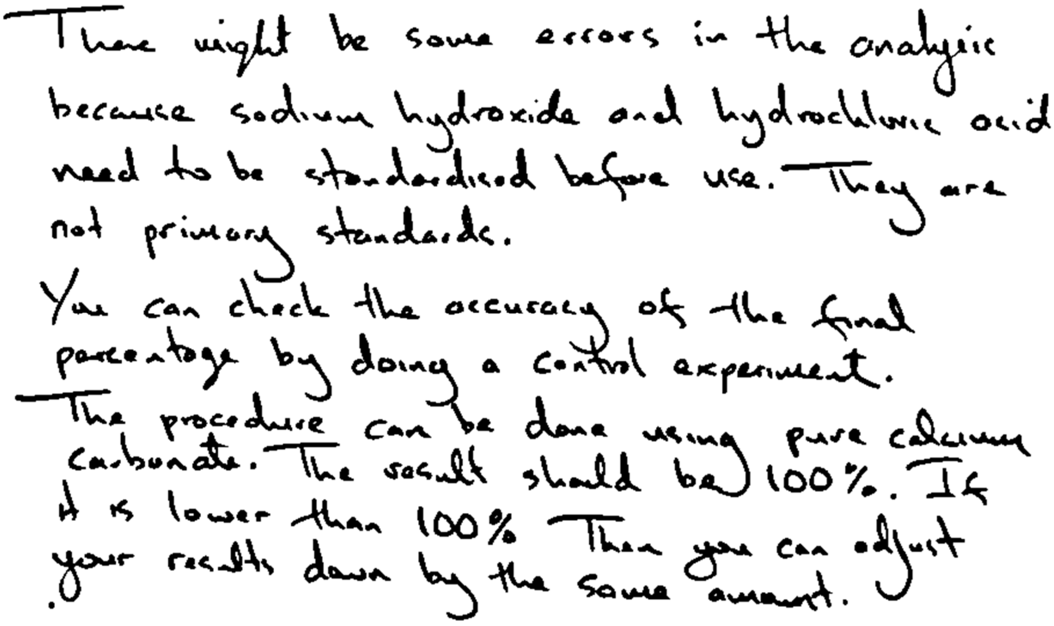
Hydrochloric acid is not a primary standard and would need to be standardised before use. You could use a standard solution of sodium carbonate to do that. Sodium hydroxide needs to be standardised too as it absorbs moisture from the atmosphere. You can use oxalic acid to do that.

To check the accuracy of the results you could do a control experiment with pure calcium carbonate.

2 marks

Overall, the candidate has shown a reasonable understanding by highlighting a possible source of error and how to correct it. They have also given a method for checking the accuracy of the final percentage, although they have not detailed how this method would work.

Example 8



There might be some errors in the analysis because sodium hydroxide and hydrochloric acid need to be standardised before use. They are not primary standards.

You can check the accuracy of the final percentage by doing a control experiment.

The procedure can be done using pure calcium carbonate. The result should be 100%. If it is lower than 100% Than you can adjust your results down by the same amount.

2 marks

Overall, the candidate has shown a reasonable understanding by highlighting a possible source of error in the solutions. The candidate has also given details of a procedure for checking the accuracy, although the final sentence is not correct.

Example 9

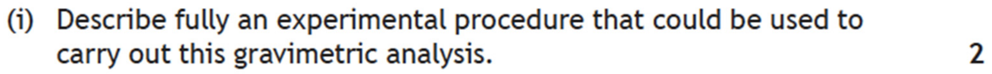
If they use the wrong indicator then the endpoint of the titration will not be accurate. For example, this titration is between a strong acid and a strong base. The endpoint will be pH7. If the indicator doesn't change colour until pH10 is reached then too much alkali will have been added and it will appear that less hydrochloric acid has reacted with the calcium carbonate. The % will be lower than it actually is.

This shouldn't matter if you do a control experiment with pure calcium carbonate. Just do the exact same experiment and the results should give you 100%. If it's less than 100% then you can use the result to scale both results up by the same amount so that the control experiment is 100%. This should give you a more accurate result.

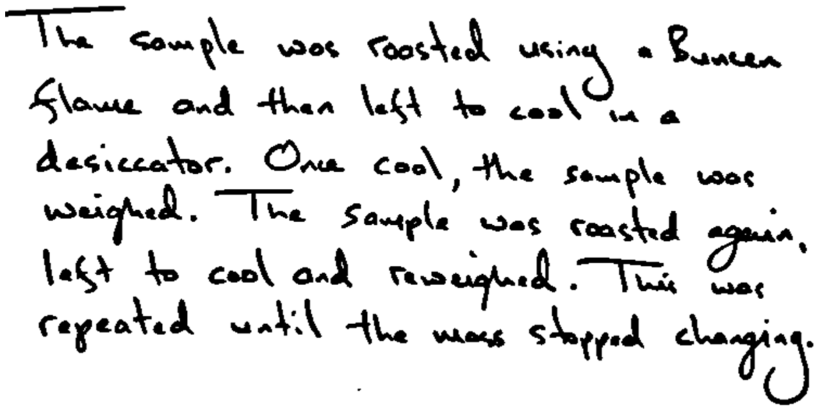
3 marks

The candidate given a good response to the problem by explaining in detail the source of the error and the effect it would have on the final result. The candidate has also suggested a way of checking the final result and what to do to make the final percentage more accurate.

Question 5(b)(i)


(i) Describe fully an experimental procedure that could be used to carry out this gravimetric analysis. 2

Example 1

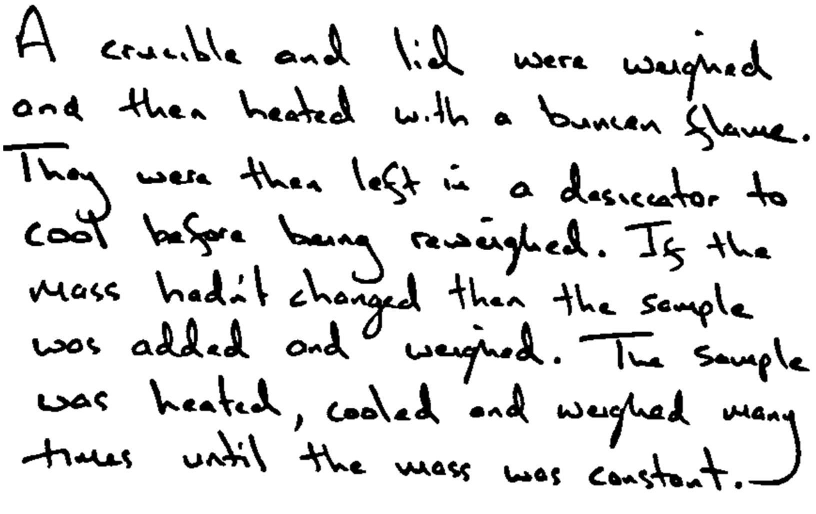

The sample was roasted using a Bunsen flame and then left to cool in a desiccator. Once cool, the sample was weighed. The sample was roasted again, left to cool and reweighed. This was repeated until the mass stopped changing.

2 marks

The first mark is awarded for mention of roasting (heating) the sample.

The second mark is awarded for mention of the three steps:
- cooling in a desiccator
- weighing
- repeating until the mass stopped changing (constant mass).

Example 2


A crucible and lid were weighed and then heated with a bunsen flame. They were then left in a desiccator to cool before being reweighed. If the mass hadn't changed then the sample was added and weighed. The sample was heated, cooled and weighed many times until the mass was constant.

2 marks

The first mark is awarded for mention of heating the sample.

The second mark is awarded for mention of the three steps:
- cooling (it can be assumed that a desiccator was used as previously)
- weighing
- repeating until the mass was constant.

Example 3

The sample is heated, left to cool and weighed many times until the mass is constant.

1 mark

The first mark is awarded for mention of heating the sample.

The second mark is not awarded since the candidate has not mentioned that the cooling takes place in a desiccator.

Example 4

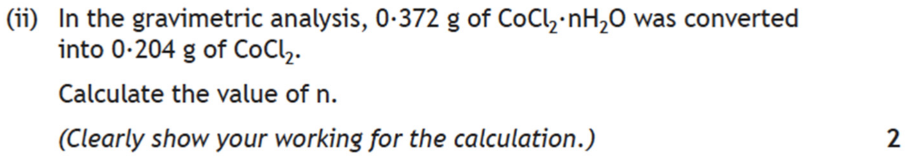
The sample is roasted in a crucible using a bunsen flame and then left to cool in a desiccator before being weighed. The process is repeated many times.

1 mark

The first mark is awarded for mention of roasting (heating) the sample.

The second mark is not awarded since the candidate has not mentioned that the process is repeated to a <u>constant mass</u>.

Question 5(b)(ii)

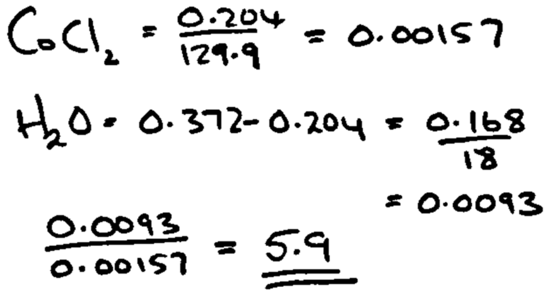


(ii) In the gravimetric analysis, 0·372 g of $CoCl_2 \cdot nH_2O$ was converted into 0·204 g of $CoCl_2$.

Calculate the value of n.

(Clearly show your working for the calculation.) 2

Example 1



$CoCl_2 = \frac{0.204}{129.9} = 0.00157$

$H_2O = 0.372 - 0.204 = \frac{0.168}{18}$

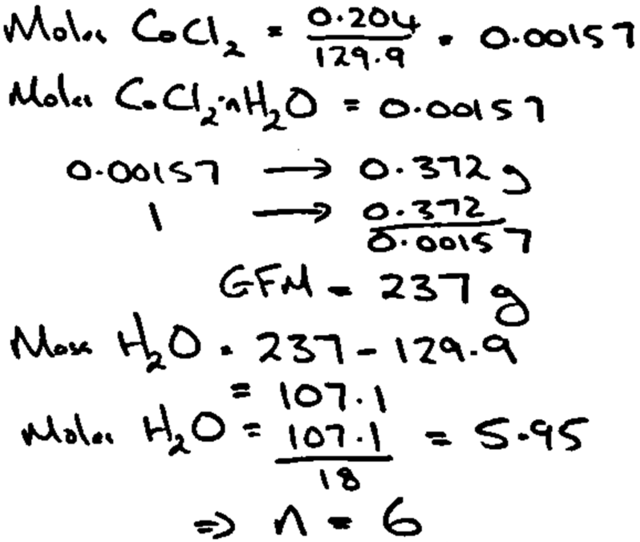
$= 0.0093$

$\frac{0.0093}{0.00157} = \underline{\underline{5.9}}$

1 mark

The final answer is not correct as it is not a whole number.
1 mark is awarded for correctly calculating the moles of $CoCl_2$ and H_2O.

Example 2



Moles $CoCl_2 = \frac{0.204}{129.9} = 0.00157$

Moles $CoCl_2 \cdot nH_2O = 0.00157$

$0.00157 \longrightarrow 0.372\,g$

$1 \longrightarrow \frac{0.372}{0.00157}$

GFM $= 237\,g$

Mass $H_2O = 237 - 129.9$

$= 107.1$

Moles $H_2O = \frac{107.1}{18} = 5.95$

$\Rightarrow n = \underline{\underline{6}}$

2 marks

The final answer has been correctly calculated. General marking instruction **(g)** applies.
There has been some intermediate rounding but to an acceptable number of significant figures.

Example 3

$$\text{GFM} = 129{\cdot}9$$

$$\text{Moles } CoCl_2 = \frac{0{\cdot}204}{129{\cdot}9}$$

$$= 0{\cdot}00106$$

$$\text{Mass } H_2O = 0{\cdot}372 - 0{\cdot}204$$

$$= 0{\cdot}168$$

$$\text{Moles } H_2O = \frac{0{\cdot}168}{18} = 0{\cdot}00933$$

$$\text{Mole ratio} = 0{\cdot}00106 : 000933$$

$$= 1 : 8{\cdot}8$$

$$\Rightarrow \underline{\underline{n = 9}}$$

1 mark

The final answer is not correct (the candidate has used 192·9 instead of 129·9 for the GFM of $CoCl_2$). 1 mark is awarded for correctly calculating a value for n from an incorrect number of moles of $CoCl_2$.

Example 4

$$CoCl_2 = \frac{0{\cdot}204}{129{\cdot}9} = 0{\cdot}002$$

$$CoCl_2{\cdot}nH_2O = \frac{0{\cdot}372}{0{\cdot}002} = 186$$

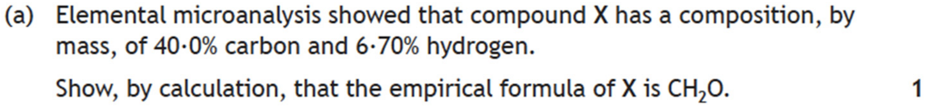
$$H_2O = 186 - 129.9$$

$$= \frac{\underline{56{\cdot}1}}{18} = \underline{\underline{3}}$$

1 mark

The final answer is not correct as the candidate has inappropriately rounded the moles of $CoCl_2$ to 1 significant figure. General marking instruction **(g)** applies. 1 mark is awarded for correctly calculating a value for n from an incorrect GFM for $CoCl_2{\cdot}nH_2O$.

Question 6(a)



(a) Elemental microanalysis showed that compound X has a composition, by mass, of 40·0% carbon and 6·70% hydrogen.

Show, by calculation, that the empirical formula of X is CH_2O. 1

Example 1

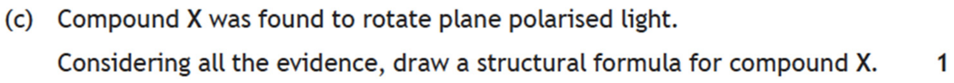
$$\begin{array}{cccc} & \underline{C} & \underline{H} & \underline{O} \\ & \frac{40}{12} & \frac{6.7}{1} & \frac{53.3}{16} \\ = & \frac{3.3}{3.3} & \frac{6.7}{3.3} & \frac{3.3}{3.3} \\ = & 1 & 2 & 1 \end{array}$$

$$\Rightarrow CH_2O$$

1 mark

The number of moles of each substance has been rounded to 2 significant figures. This is acceptable since it still gives the correct empirical formula.

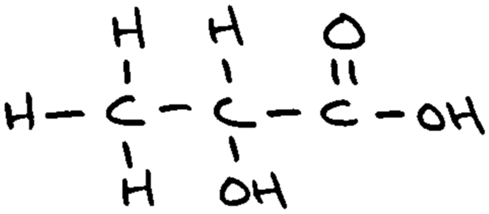
Question 6(c)



(c) Compound X was found to rotate plane polarised light.

Considering all the evidence, draw a structural formula for compound X. 1

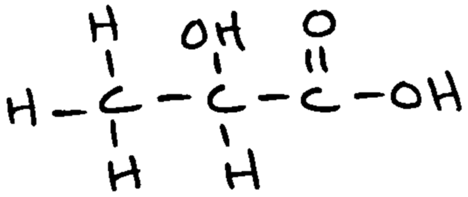
Example 1



1 mark

The connectivity of the hydroxyl group to the middle carbon looks suspect, however, on extending the bond it would touch the oxygen atom.

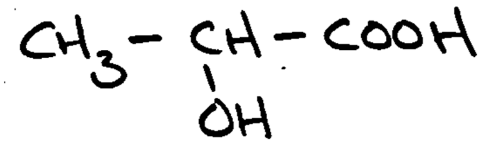
Example 2



0 marks

The connectivity of the hydroxyl group to the middle carbon is not correct. The bond goes between the hydrogen and oxygen atoms. Marking instruction (l) applies.

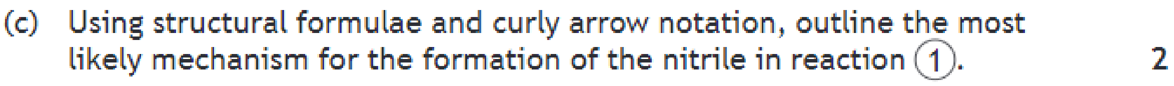
Example 3



0 marks

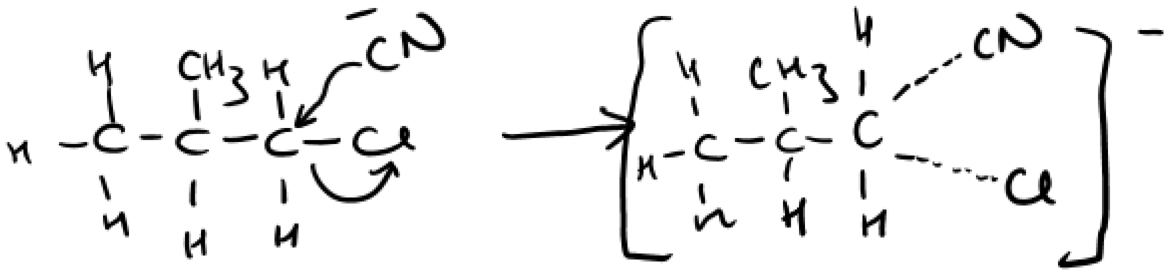
The connectivity of the CH_3 and CH is wrong. General marking instruction **(l)** applies.

Question 7(c)



(c) Using structural formulae and curly arrow notation, outline the most likely mechanism for the formation of the nitrile in reaction ①. 2

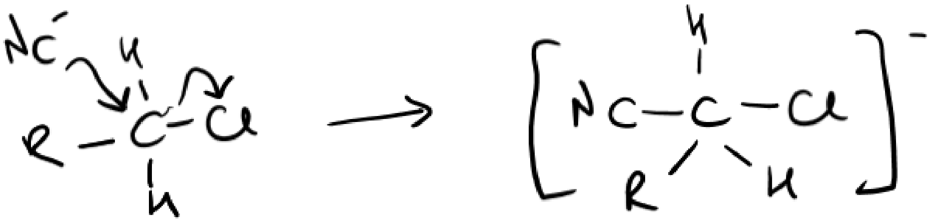
Example 1



1 mark

Although the curly arrow from the CN^- is not particularly well drawn, this would be acceptable and so the mark for curly arrows is awarded. The intermediate shows the five membered transition state and includes the negative charge but there is incorrect connectivity between the carbon atom and the methyl group – if this line was extended it would show the carbon atom attaching to the H of the CH_3 rather than the C.

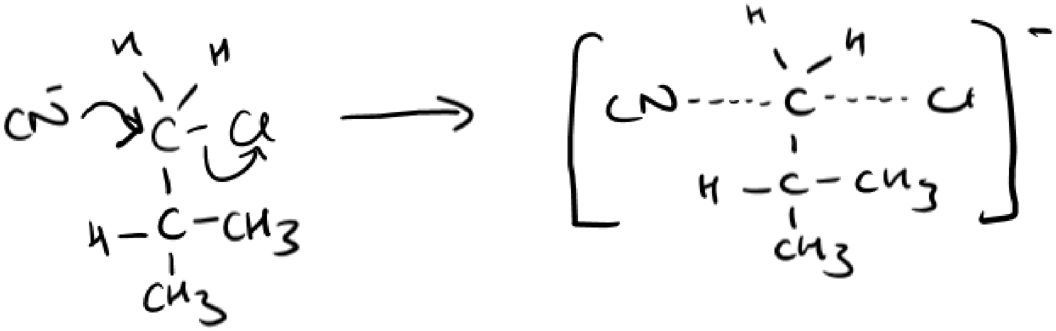
Example 2



1 mark

Although the curly arrow from the CN^- is not particularly well drawn, this would be acceptable and so the mark for curly arrows is awarded. The intermediate shows the five membered transition state and includes the negative charge but abbreviating the rest of the molecule to R does not allow for the connectivity of all of the atoms in the transition state to be checked.

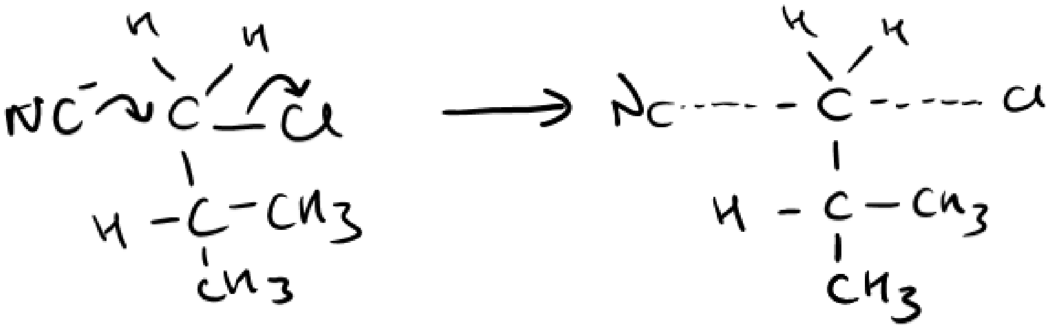
Example 3



0 marks

The curly arrow from the CN^- is starting at the nitrogen atom rather than the carbon atom and so the mark for curly arrows cannot be awarded. The intermediate shows the five membered transition state and includes the negative charge but there is incorrect connectivity between the carbon atom and the bottom methyl group.

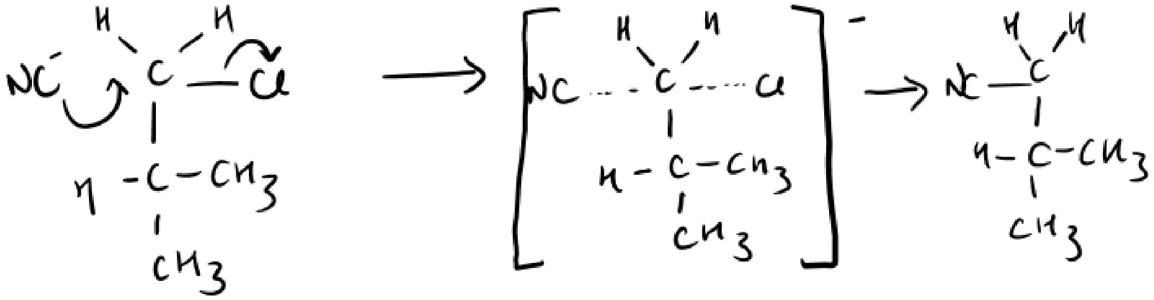
Example 4



1 mark

The candidate has correctly drawn both curly arrows and so 1 mark is awarded. The transition state does not have a negative charge and so this mark cannot be awarded.

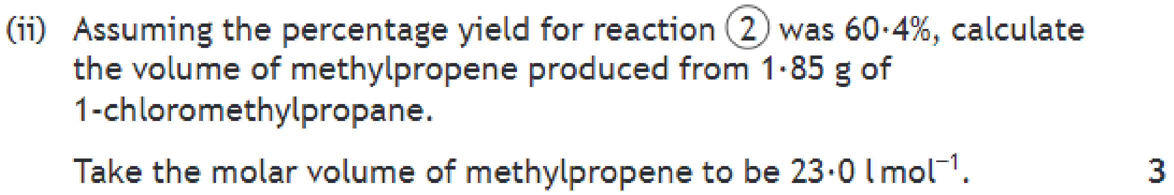
Example 5



2 marks

The candidate has correctly drawn both curly arrows and the transition state and so 2 marks are awarded. The final product has been drawn with incorrect connectivity to the bottom methyl group but this does not count as a cancelling error as only the correct connectivity in the transition state is being assessed.

Question 7(d)(ii)



(ii) Assuming the percentage yield for reaction ② was 60·4%, calculate the volume of methylpropene produced from 1·85 g of 1-chloromethylpropane.

Take the molar volume of methylpropene to be 23·0 $l\,mol^{-1}$. 3

Example 1

$C_4H_9Cl \rightarrow C_4H_8$

92.5 → 56g

1.85 g → 1.12 g

60.4% ⇒ 0.67648g = 0.7g

56g → 23 litres

0.7 → 0.288 litres

2 marks

The candidate has rounded the value for the actual mass of methylpropene to an incorrect number of significant figures – general marking instruction **(g)** applies. This has resulted in an incorrect volume being calculated. 1 mark is awarded for calculating the theoretical yield of methylpropene OR correctly multiplying by 23. 1 mark is awarded for the correct unit for the calculated value.

Example 2

$C_4H_9Cl \rightarrow C_4H_8$

1.85g

$n = \frac{1.85}{92.5} = 0.02$

60.4% of 0.02 = 0.012

1mole → 23 litres

0.012 → 0.27 litres

2 marks

The final answer has been rounded incorrectly. 1 mark is awarded for the correct calculation of 60·4% of 0·02. 1 mark is awarded for the correct units for a calculated volume.

Example 3

number of moles 1-chloromethylpropane $= \frac{1·85}{92·5}$

$= 0·02$

volume of methylpropene $= 0·02 \times 23$

$= 0·46$ litres

2 marks

The candidate has not calculated the actual yield. 1 mark is awarded for calculating the theoretical yield of methylpropene and 1 mark is awarded for a correct unit for a calculated volume.

Example 4

$n = \frac{1·85}{56} = 0·033$ moles

60·4% of $0·033 = 0·02$

$002 \times 23 = 0·46$

1 mark

There is no unit for the final calculated volume and so the mark for the correct unit cannot be awarded. This would apply even if general marking instruction **(h)** has been applied in the paper. The incorrect GFM has been used leading to an incorrect number of moles. Although the candidate has calculated 60·4% of an incorrect theoretical yield this has been quoted to too few significant figures and so marking instruction (g) applies. 1 mark is awarded for multiplying an incorrect number of moles by 23.

Example 5

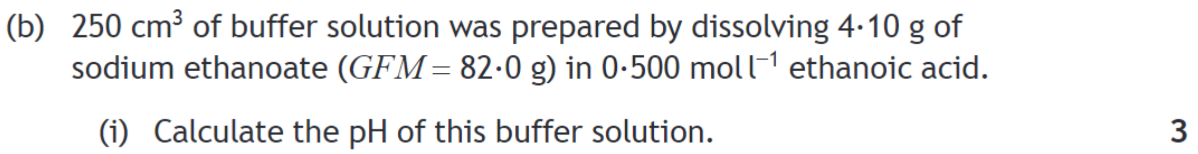
$n = \frac{1·85}{56} = 0·033$ moles

$0·033 \times 23 = 0·759\ cm^3$

1 mark

The unit given is not correct for the volume calculated and so this mark cannot be awarded. 1 mark is awarded for correctly multiplying an incorrect number of moles by 23.

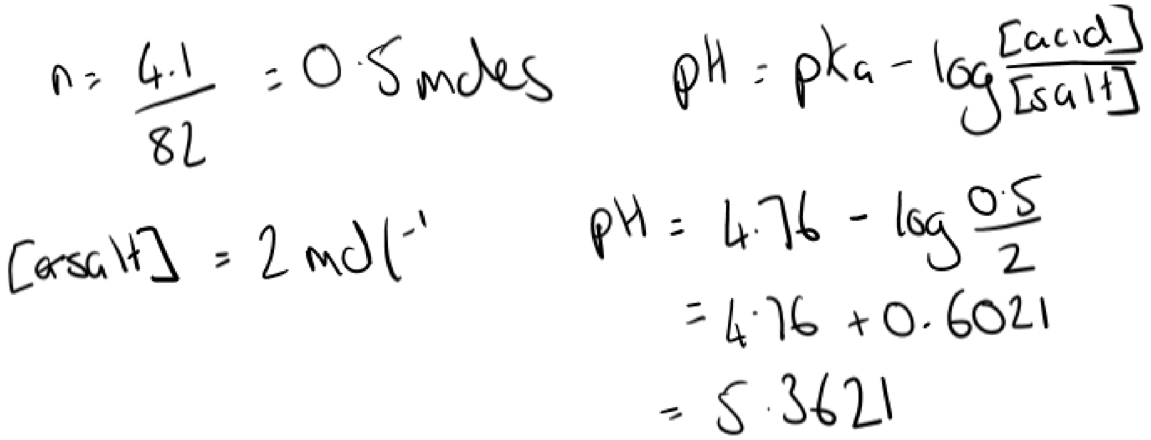
Question 8(b)(i)



(b) 250 cm^3 of buffer solution was prepared by dissolving 4·10 g of sodium ethanoate ($GFM = 82·0$ g) in 0·500 mol l^{-1} ethanoic acid.

(i) Calculate the pH of this buffer solution. **3**

Example 1



$n = \frac{4.1}{82} = 0.5$ moles

[salt] = 2 mol l^{-1}

$pH = pKa - \log\frac{[acid]}{[salt]}$

$pH = 4.76 - \log\frac{0.5}{2}$

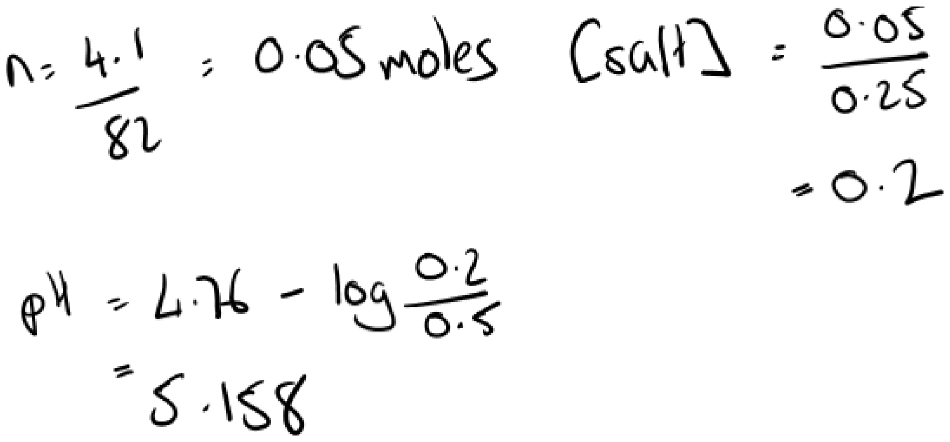
$= 4.76 + 0.6021$

$= 5.3621$

2 marks

The concentration of salt has been calculated incorrectly. 2 marks are awarded for a correct calculation of pH from an incorrect concentration of salt. The final answer is quoted to 5 significant figures and this is within the acceptable range for the data in this question.

Example 2



$n = \frac{4.1}{82} = 0.05$ moles

$[salt] = \frac{0.05}{0.25}$

$= 0.2$

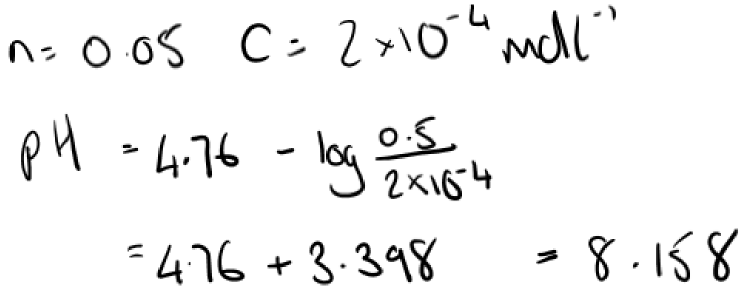
$pH = 4.76 - \log\frac{0.2}{0.5}$

$= 5.158$

1 mark

The calculation of pH has the [salt]/[acid] and this is incorrect (unless the equation is quoted as pK_a + log([salt]/[acid])). As the equation has not been stated it is not possible to award a partial mark for the correct equation. The candidate has correctly calculated the concentration of the salt and although this value is not quoted to the correct number of significant figures, the marking instructions state that this is acceptable.

Example 3



$n = 0.05 \quad C = 2\times10^{-4}\ \text{mol l}^{-1}$

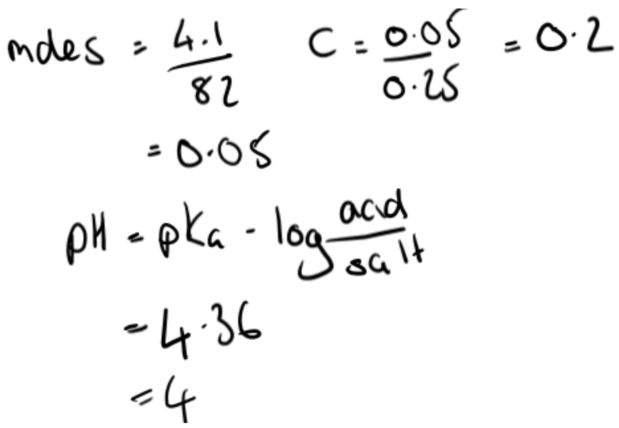
$pH = 4.76 - \log\frac{0.5}{2\times10^{-4}}$

$= 4.76 + 3.398 \quad = 8.158$

1 mark

The candidate has incorrectly calculated the concentration of the salt and has made an error in the calculation of the pH. 1 mark is awarded for a correct substitution into the equation.

Example 4



$\text{moles} = \frac{4.1}{82} \quad C = \frac{0.05}{0.25} = 0.2$

$= 0.05$

$pH = pKa - \log\frac{\text{acid}}{\text{salt}}$

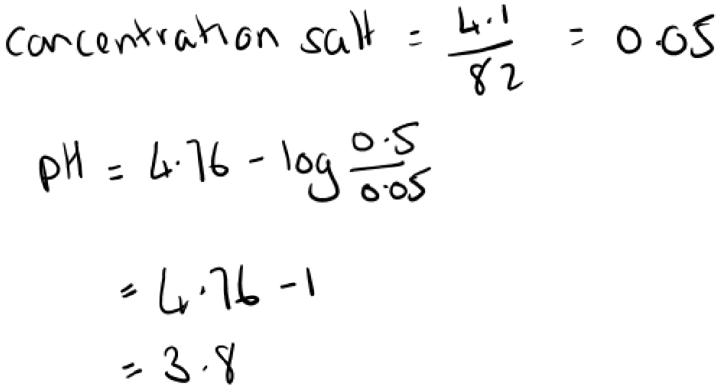
$= 4.36$

$= 4$

2 marks

The final answer is quoted 1 significant figure and this is out with the acceptable range and so general marking instruction **(e)** applies. 1 mark is deducted assuming that this is the first time the significant figures rule or the units rule has been applied in the paper. The candidate has correctly calculated the concentration of the salt and has written the correct equation and so 2 marks are awarded.

Example 5



$\text{concentration salt} = \frac{4.1}{82} = 0.05$

$pH = 4.76 - \log\frac{0.5}{0.05}$

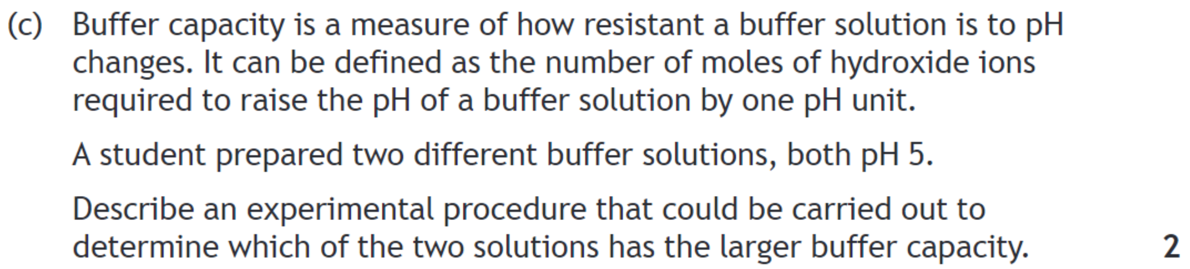
$= 4.76 - 1$

$= 3.8$

2 marks

The candidate has incorrectly calculated the concentration of the salt. 2 marks are awarded for correctly calculating a pH from an incorrect concentration of salt and the final answer has 2 significant figures which is within the acceptable range.

Question 8(c)

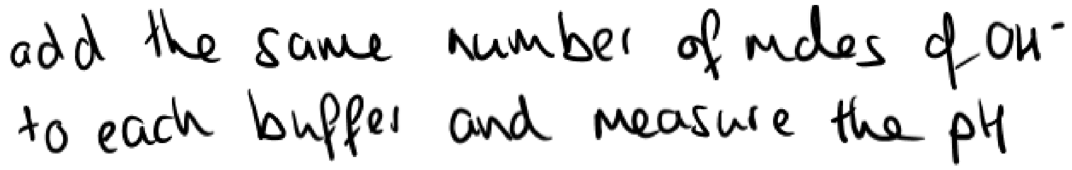


(c) Buffer capacity is a measure of how resistant a buffer solution is to pH changes. It can be defined as the number of moles of hydroxide ions required to raise the pH of a buffer solution by one pH unit.

A student prepared two different buffer solutions, both pH 5.

Describe an experimental procedure that could be carried out to determine which of the two solutions has the larger buffer capacity. **2**

Example 1

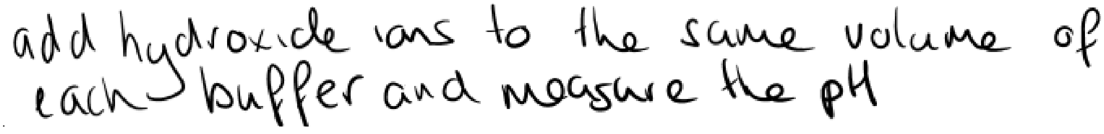


add the same number of moles of OH^- to each buffer and measure the pH

1 mark

1 mark is awarded for correctly stating that the same number of moles of OH^- are added to each buffer and the pH is measured but has not stated that the volume of each buffer must be the same.

Example 2

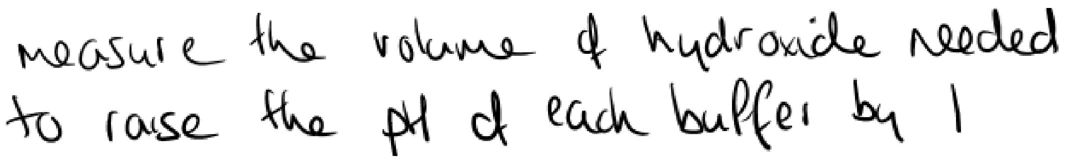


add hydroxide ions to the same volume of each buffer and measure the pH

1 mark

The candidate has stated that the same volume of each buffer is used and so is awarded 1 mark. There has been no mention of controlling the volume/moles of hydroxide and so the second mark cannot be awarded.

Example 3

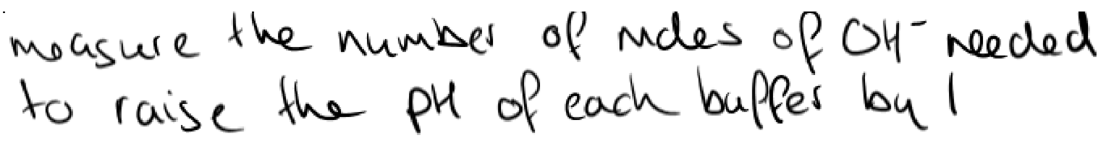


measure the volume of hydroxide needed to raise the pH of each buffer by 1

1 mark

The candidate has stated that the volume of hydroxide needed to raise the pH by 1 should be measured but has not stated that the volume of each buffer must be the same.

Example 4

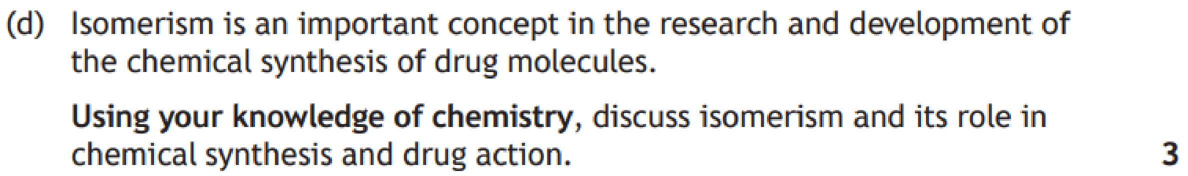


measure the number of moles of OH^- needed to raise the pH of each buffer by 1

0 marks

The candidate has simply restated the information in the question and has not described an experimental procedure nor is there a mention of the volume of buffer solution used.

Question 9(d)

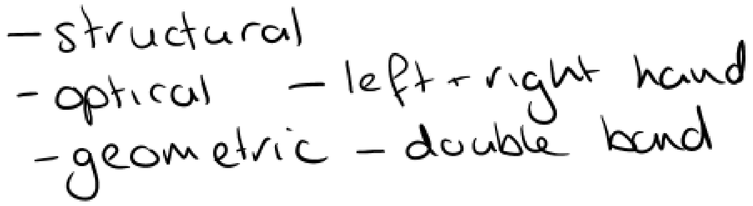


(d) Isomerism is an important concept in the research and development of the chemical synthesis of drug molecules.

Using your knowledge of chemistry, discuss isomerism and its role in chemical synthesis and drug action. **3**

Remember, open-ended questions are marked holistically according to whether the candidate has provided a good, reasonable or limited response to the problem at Advanced Higher level. Zero marks can be awarded if the response is not related to the problem or not at an appropriate level.

Example 1

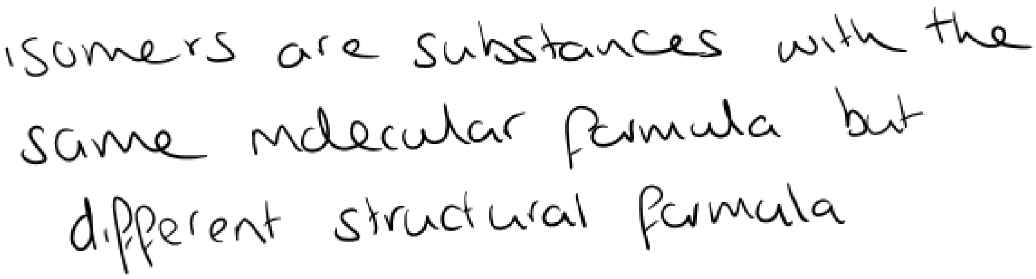


– structural
- optical – left + right hand
-geometric – double bond

1 mark

The candidate has demonstrated, at an appropriate level, a limited understanding of the chemistry involved by accurately listing the types of isomers at an AH level. This statement is relevant to the situation, showing that they have understood at least a little of the chemistry within the problem.

Example 2



isomers are substances with the same molecular formula but different structural formula

0 marks

Although the candidate has an accurate definition of an isomer this is not an AH level definition and so the candidate has not demonstrated an understanding of the chemistry involved at an appropriate level.

Example 3

Many drugs are molecules with chiral centres (4 different groups around the carbon atom). Molecules with chiral centres have optical isomers and so will ~~have~~ exist as enantiomers Receptors ~~with~~ are chiral environments and so only one optical isomer will bond to the receptor

When chemists make drugs they need to make sure the molecule is the correct enantiomer

2 marks

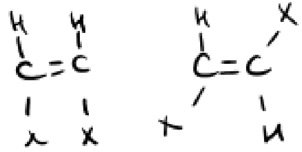
The candidate has demonstrated a reasonable understanding of the chemistry involved and this is at an AH level. More detail could have been provided about both the role of isomerism in drug action and there is only a superficial mention of the role of isomerism in synthesis.

Example 4

isomers - geometric

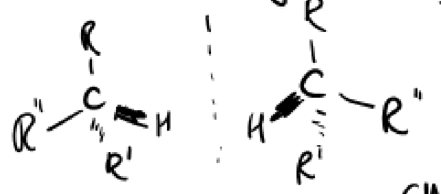
cis trans

same side



opposite sides

optical - mirror images



- drug active sites only work with one isomer

synthesis of drugs needs to make sure correct isomer is formed

nucleophilic substitution reactions can affect which isomer is formed.

SN1 reactions have a trigonal carbocation intermediate and so a racemic mix forms

SN2 reactions have a trigonal bipyramidal intermediate and so the opposite isomer forms compared the ~~s~~ reactant.

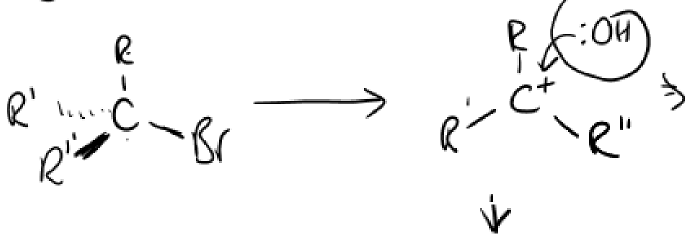
3 marks

The candidate has demonstrated a good understanding of the chemistry involved and at an appropriate level for AH. The chemistry is accurate and although more detail could have been provided overall a good understanding has been demonstrated.

Example 5

Nucleophilic substitution reactions
of haloalkanes - isomerism - optical

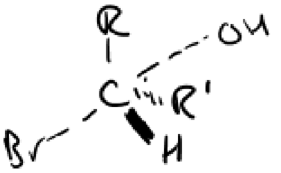
SN1 - carbocation intermediate



⇒ flat

the nucleophile ⁻OH can attack from either direction and so the new product will have a mix of optical isomers

SN2 - 5 membered ⇒ reverses
stereochemistry

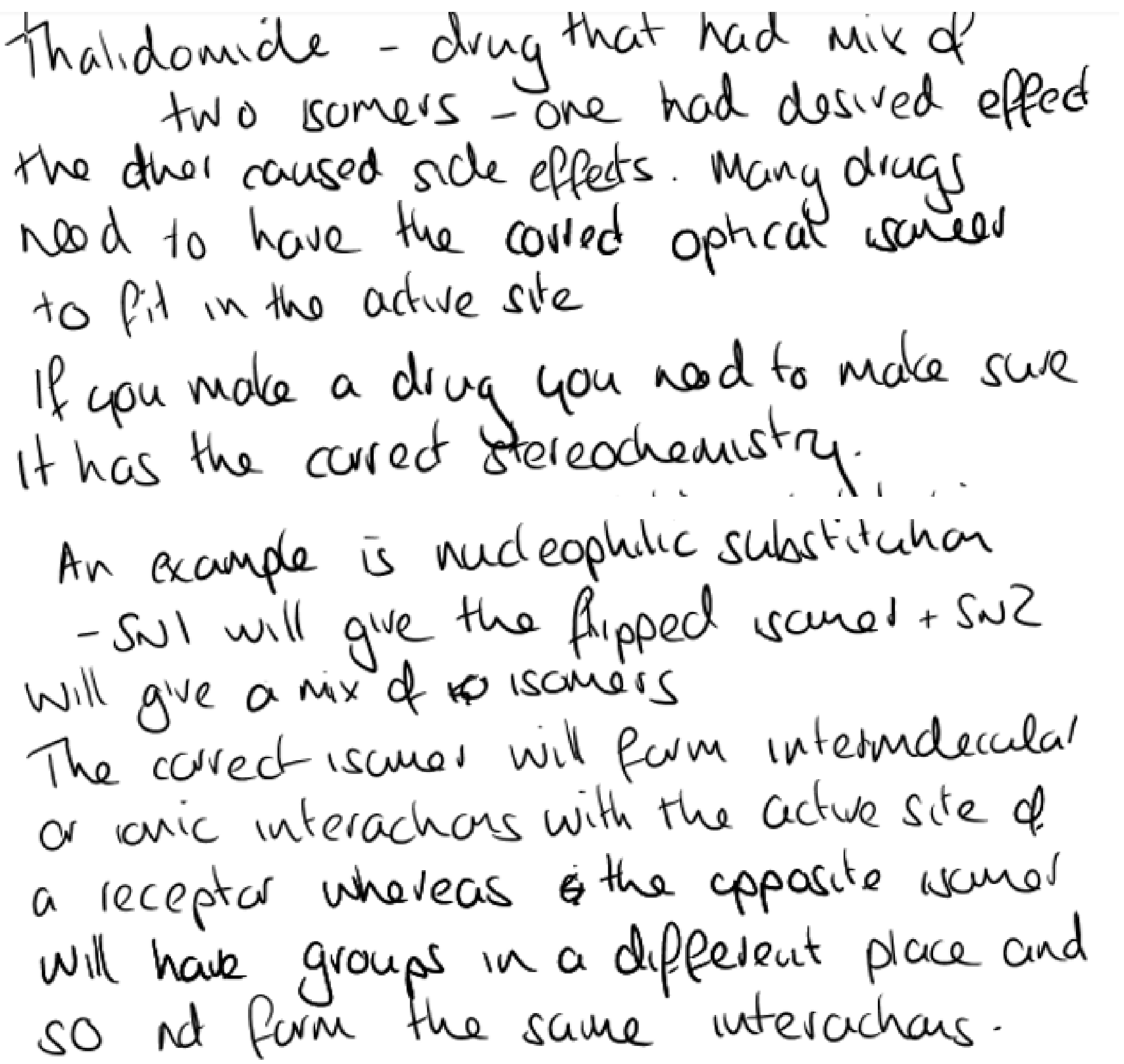


⇒ product is the
opposite optical
isomer

3 marks

The candidate response has demonstrated a good understanding of the chemistry and this is at an appropriate level. There is no mention of drug action but the answer does not need to be complete to be awarded 3 marks.

Example 6



Thalidomide - drug that had mix of two isomers - one had desired effect the other caused side effects. Many drugs need to have the correct optical isomer to fit in the active site

If you make a drug you need to make sure it has the correct stereochemistry.

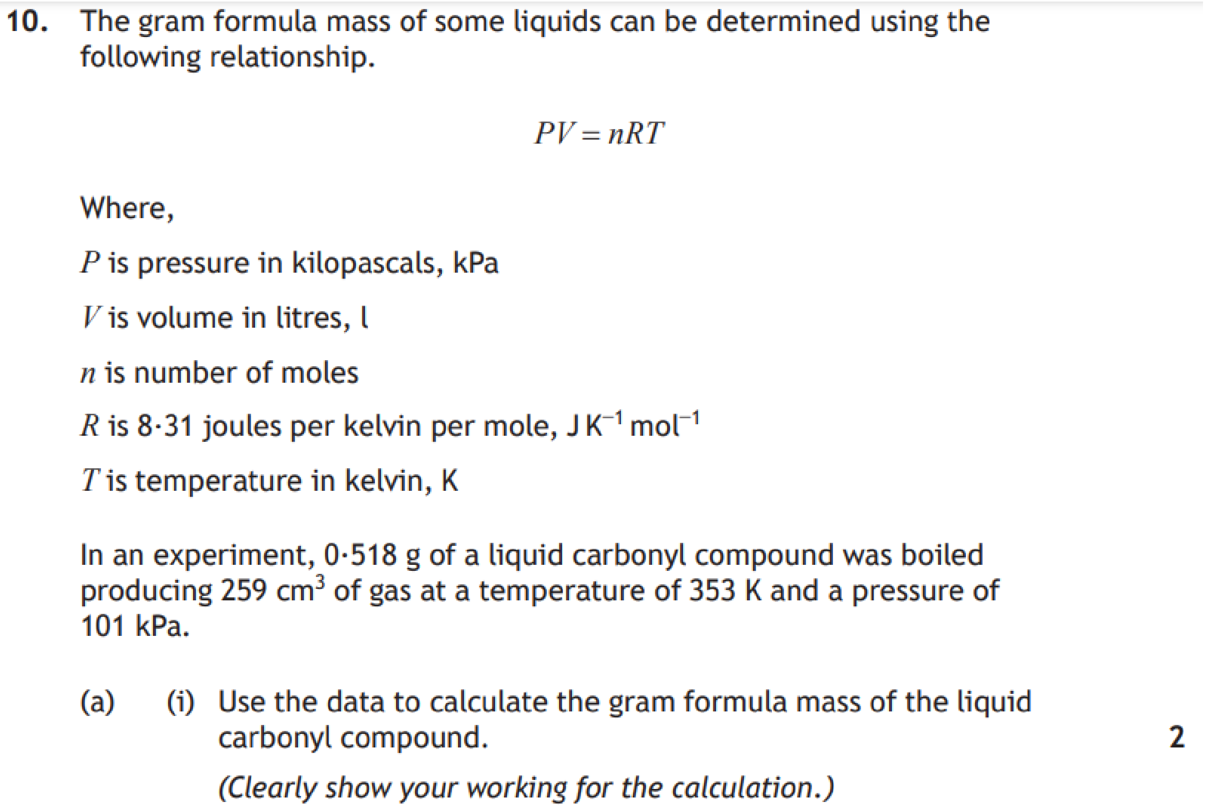
An example is nucleophilic substitution - S_N1 will give the flipped isomer + S_N2 will give a mix of isomers

The correct isomer will form intermolecular or ionic interactions with the active site of a receptor whereas the opposite isomer will have groups in a different place and so not form the same interactions.

2 marks

Overall the candidate has demonstrated a good understanding of the chemistry of the question. An accurate description of the role of isomerism in drug action has been given. There has been an error in the isomerism of S_N1 and S_N2 reactions leading to a reasonable understanding being demonstrated.

Question 10(a)(i)



10. The gram formula mass of some liquids can be determined using the following relationship.

$$PV = nRT$$

Where,

P is pressure in kilopascals, kPa

V is volume in litres, l

n is number of moles

R is 8·31 joules per kelvin per mole, $\text{J K}^{-1}\,\text{mol}^{-1}$

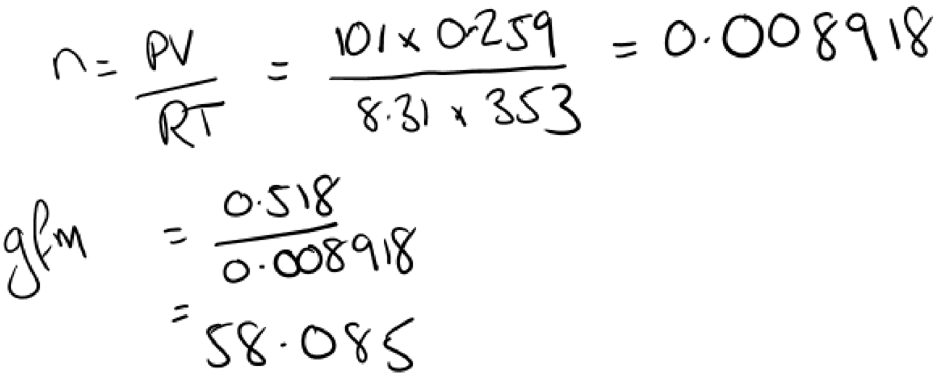
T is temperature in kelvin, K

In an experiment, 0·518 g of a liquid carbonyl compound was boiled producing 259 cm^3 of gas at a temperature of 353 K and a pressure of 101 kPa.

(a) (i) Use the data to calculate the gram formula mass of the liquid carbonyl compound. **2**

(Clearly show your working for the calculation.)

Example 1



$$n = \frac{PV}{RT} = \frac{101 \times 0{\cdot}259}{8{\cdot}31 \times 353} = 0{\cdot}008918$$

$$\text{gfm} = \frac{0{\cdot}518}{0{\cdot}008918}$$

$$= 58{\cdot}085$$

2 marks

The candidate has used the rounded value of 0.008918 which is covered in the marking instructions. General marking instruction **(g)** applies. This rounded number is within the acceptable range for significant figures (between 2 and 5) and so the final answer is correct. The final answer is also within the allowed range of significant figures.

Example 2

$$n = \frac{101 \times 0.259}{8.31 \times 353} = 0.008917547$$

$$gfm = n \times M$$
$$= 0.00462$$

1 mark

The gfm has been incorrectly calculated. 1 mark is awarded for calculating the number of moles. The number is written with too many significant figures, but this is not a final answer and so the mark is awarded.

Example 3

$$n = \frac{101 \times}{8.31} 8.918 \; 8.918$$

$$gfm = \frac{0.518}{8.918} = 0.0581$$

1 mark
The candidate has not converted the volume into litres. 1 mark is awarded for the correct calculation of gfm from an incorrect number of moles and so is a correct follow through. The final value is stated to the correct number of significant figures.

Example 4

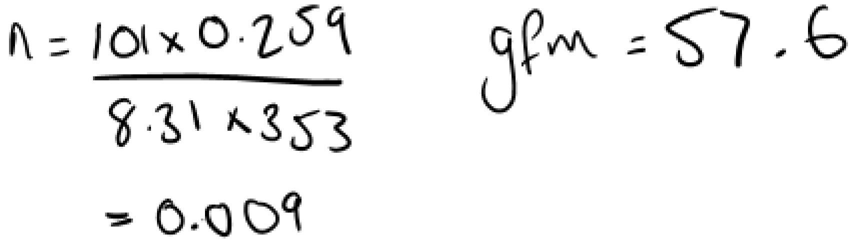
$$n = \frac{8.31 \times 353}{101 \times 0.259} = 112.14$$

$$gfm = \frac{0.518}{112.14} = 0.00462$$

1 mark

The candidate has rearranged the equation incorrectly and so has calculated an incorrect number of moles. 1 mark is awarded for the correct calculation of gfm from an incorrect number of moles and so is a correct follow through and the final answer is given with the correct number of significant figures.

Example 5



$$n = \frac{101 \times 0.259}{8.31 \times 353}$$

$$= 0.009$$

$$gfm = 57.6$$

1 mark

The value for the number of moles has been rounded to too few significant figures and so general marking instruction **(g)** applies. 1 mark is awarded for the correct calculation of gfm from an incorrect number of moles.

Question 11(a)(ii)

(ii) A solution of iodine was prepared by dissolving iodine in 0·239 mol l^{-1} aqueous potassium iodide.

The following data was obtained by analysing the equilibrium mixture.

$$[I_2(aq)] = 1{\cdot}21 \times 10^{-3}\ \text{mol l}^{-1}$$
$$[I_3^-(aq)] = 0{\cdot}116\ \text{mol l}^{-1}$$

Calculate the equilibrium constant, K, for this reaction. **2**

Example 1

$$K = \frac{[I_3^-]}{[I_2][I^-]} = \frac{0.116}{1{\cdot}21\times10^{-3} \times 0{\cdot}239}$$
$$= 401{\cdot}12$$

1 mark

The candidate has incorrectly used the value of 0·239 as the concentration of iodide and this is covered in the marking instructions. 1 mark is awarded for correctly calculating a value for K from an incorrect concentration of I$^-$. The significant figures quoted are within the acceptable range.

Example 2

$$K = \frac{0{\cdot}116}{1{\cdot}21\times10^{-3} \times 1{\cdot}21\times10^{-3}}$$
$$= 79230$$

1 mark

The candidate has incorrectly used the value of 1·21 x 10^{-3} as the concentration of iodide. 1 mark is awarded for correctly calculating a value for K from an incorrect concentration of I$^-$. The significant figures quoted are within the acceptable range.

Example 3

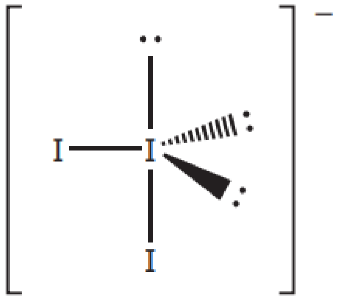
$$I^- + I_2 \rightleftharpoons I_3^-$$
$$(0{\cdot}239 - 0{\cdot}116) \quad 1{\cdot}21\times10^{-3} \quad 0{\cdot}116$$
$$0{\cdot}123$$
$$K = \frac{0{\cdot}116}{0{\cdot}123 \times 1{\cdot}2 \times 10^{-3}}$$
$$= 785{\cdot}91$$

1 mark

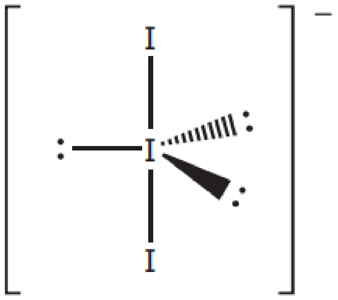
There is an error in the calculation of K (incorrect concentration of I$_2$). The candidate has correctly calculated the concentration of I$^-$.

Question 11 (b)

(b) Structures **A** and **B** show two possible arrangements of the electron pairs around the central iodine atom in a triiodide ion, I_3^-.



A



B

•• denotes a non-bonding electron pair.

Explain fully why the electron pairs around the central iodine atom adopt structure **B** rather than structure **A**. 2

Example 1

minimises repulsions

1 mark

The candidate has correctly stated that repulsions are minimised and so this is awarded one mark. There is no link to the angle or distance between the lone pairs or bonding pairs and so the second mark is not awarded.

Example 2

lone pairs are further away from each other

1 mark

The candidate has correctly stated that the lone pairs are further away and given the wording of the question it can be assumed they are referring to B. There is no mention of minimising repulsions and so the first mark is not awarded.

Example 3

it is more stable

0 marks

The candidate has not mentioned the repulsion or the angle of electron pairs and so no mark can be awarded.

Example 4

iodine atoms are further apart

0 marks

The candidate has described structure B but has not mentioned repulsions or distance between electron pairs.

Example 5

lone pairs are further apart + this minimises repulsion between bonding pairs

1 mark

The candidate has made a correct statement about the distance between lone pairs and given the wording of the question it can be assumed they are referring to B. The statement about repulsion is incorrect and so the first mark cannot be awarded.

Example 6

minimises repulsions as lone pairs are all in the middle

1 mark

The answer correctly states that repulsions are minimised but the second mark cannot be awarded as the angle or distance between lone pairs has not been stated.

Question 12(f)(i)

(i) Explain fully why an aqueous solution of sodium benzoate is alkaline. **2**

Example 1

It is the salt of a strong base and a weak acid. This means that there are extra OH^- ions produced in the water equilibrium

1 mark

1 mark is awarded for the statement that the water equilibrium produces more OH^- ions. Zero marks are awarded for stating that it is the salt of a weak acid and a strong base.

Example 2

Sodium benzoate fully dissociates into ions
The benzoate ion forms an equilibrium with H^+ from water and so H^+ ions are removed from water equilibrium

1 mark

The candidate has correctly stated that the benzoate ions remove the H^+ ions from the water equilibrium and so 1 mark is awarded. There is no mention on the effect of OH^- ions and so the second mark cannot be awarded.

Example 3

sodium benzoate → sodium ions + benzoate ions

$H_2O \rightleftharpoons H^+ + OH^-$

H^+ ions and benzoate ions react to make benzoic acid + this results in H^+ ions being removed. Excess OH^- ions left.

2 marks

The candidate has correctly shown that H^+ ions from the water equilibrium react with benzoate ions and has also stated that this results in excess of OH^- ions.

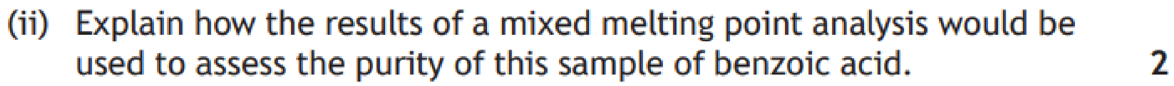
Example 4

salt of weak acid + strong base so
there are more OH^- ions than H^+ ions
due to removing H^+ ions from water equilibrium

1 mark

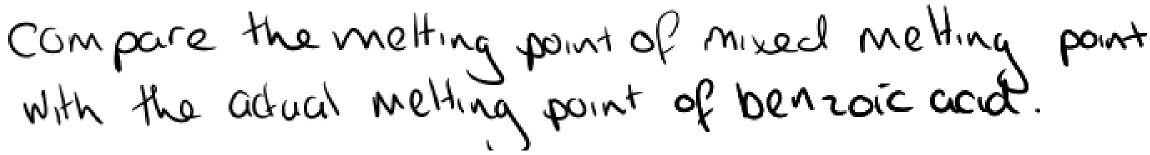
1 mark is awarded for stating that the removal of H^+ ions results in more OH^- ions. The candidate has not stated that benzoate ions remove hydrogen ions from the water equilibrium and so the first mark cannot be awarded.

Question 12 (h) (ii)



(ii) Explain how the results of a mixed melting point analysis would be used to assess the purity of this sample of benzoic acid. **2**

Example 1

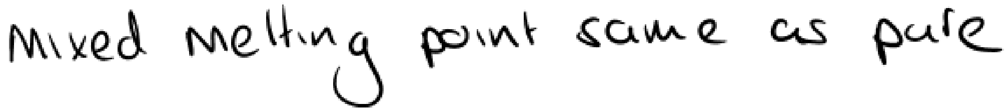


Compare the melting point of mixed melting point
with the actual melting point of benzoic acid.

1 mark

1 mark is awarded for stating that the mixed melting point needs to be compared to pure benzoic acid and although the word pure is not stated the word 'actual' is sufficient. There is no mention of how this links to the purity and so only 1 mark is awarded.

Example 2

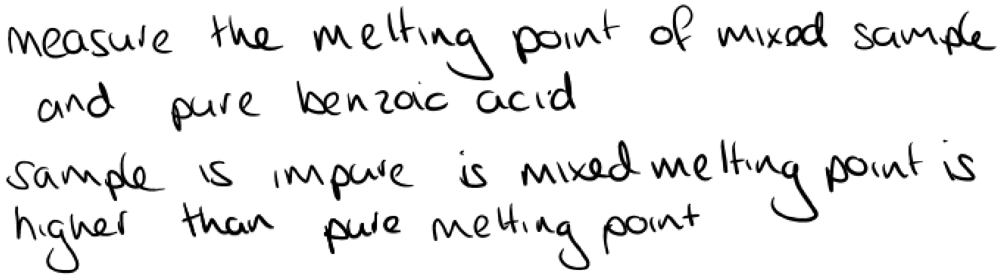


Mixed melting point same as pure

1 mark

The candidate has correctly stated that the mixed melting point should be compared to a pure sample. There has been no link to how this relates to the purity of the sample.

Example 3

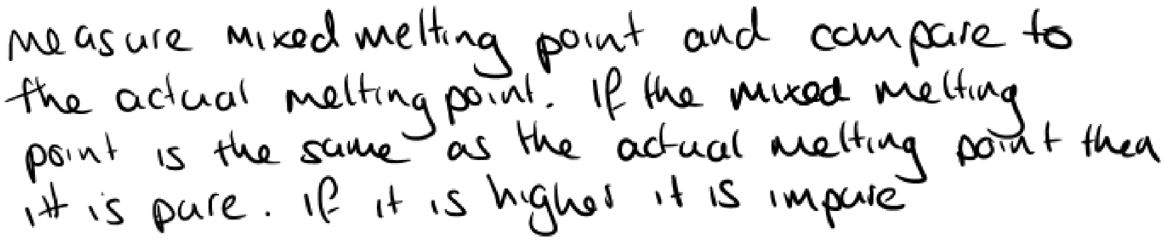


measure the melting point of mixed sample
and pure benzoic acid
sample is impure is mixed melting point is
higher than pure melting point

1 mark

The candidate has correctly stated that the mixed melting point should be compared to a pure sample. Although there is a statement linking the purity to the melting point, this is an incorrect statement and so the second mark is not awarded.

Example 4



measure mixed melting point and compare to
the actual melting point. If the mixed melting
point is the same as the actual melting point then
it is pure. If it is higher it is impure

1 mark

The candidate has correctly stated that the mixed melting point should be compared to a pure sample. The candidate has also correctly linked the purity to the melting point by stating that 'if the mixed melting point is the same as the actual melting point then it is pure'. The final statement is incorrect, and so the second mark cannot be awarded.

2021 Advanced Higher Chemistry Question Paper breakdown

This document provides the structure of the 2021 questions in Section 1 and Section 2 by Key Area; Knowledge/Skill; intended grade A marks.

Section 1

Question	Key Area of Course	Question Type	Grade A
1	Atomic orbitals, electronic configurations and the periodic table	Knowledge and understanding - making statements	
2	Electromagnetic radiation and atomic spectra	Processing information (using calculations significant figures and units, where appropriate)	1
3	Transition metals	Applying knowledge to new situations, interpreting, solving problems	
4	Chemical equilibrium	Processing information (using calculations significant figures and units, where appropriate)	1
5	Reaction feasibility	Applying knowledge to new situations, interpreting, solving problems	
6	Reaction feasibility	Applying knowledge to new situations, interpreting, solving problems	
7	Kinetics	Applying knowledge to new situations, interpreting, solving problems	
8	Kinetics	Applying knowledge to new situations, interpreting, solving problems	
9	Kinetics	Applying knowledge to new situations, interpreting, solving problems	
10	Synthesis	Applying knowledge to new situations, interpreting, solving problems	
11	Synthesis	Applying knowledge to new situations, interpreting, solving problems	
12	Molecular orbitals	Applying knowledge to new situations, interpreting, solving problems	
13	Synthesis	Applying knowledge to new situations, interpreting, solving problems	
14	Synthesis	Applying knowledge to new situations, interpreting, solving problems	
15	Non-specific	Processing information (using calculations significant figures and units, where appropriate)	
16	Synthesis	Knowledge and understanding - making statements	
17	Experimental determination of structure	Making predictions based on evidence/information	1
18	Synthesis	Applying knowledge to new situations, interpreting, solving problems	
19	Non-specific	Making predictions based on evidence/information	
20	Synthesis	Applying knowledge to new situations, interpreting, solving problems	
21	Experimental determination of structure	Drawing valid conclusions and giving explanations supported by evidence/justification	
22	Non-specific	Processing information (using calculations significant figures and units, where appropriate)	1

Section 1

Question	Key Area of Course	Question Type	Grade A
23	Experimental determination of structure	Processing information (using calculations significant figures and units, where appropriate)	1
24	Non-specific	Processing information (using calculations significant figures and units, where appropriate)	
25	Stoichiometric calculations	Applying knowledge to new situations, interpreting, solving problems	1

Section 2

Question	Area of Course	Question Type	A-type
1(a)	Electromagnetic radiation and atomic spectra	Demonstrating knowledge and understanding of chemistry by providing descriptions and explanations and integrating knowledge	
1(b)(i)	Electromagnetic radiation and atomic spectra	Applying knowledge to new situations, interpreting, solving problems	
1(b)(ii)	Electromagnetic radiation and atomic spectra	Selecting information	
1(c)(i)	Reaction feasibility	Demonstrating knowledge and understanding of chemistry by providing descriptions and explanations and integrating knowledge	
1(c)(ii)	Reaction feasibility	Applying knowledge to new situations, interpreting, solving problems	
2(a)	Transition metals	Applying knowledge to new situations, interpreting, solving problems	
2(b)	Transition metals	Applying knowledge to new situations, interpreting, solving problems	
2(c)(i)	Transition metals	Applying knowledge to new situations, interpreting, solving problems	1
2(c)(ii)	Transition metals	Knowledge and understanding - making statements	
2(d)(i)	Kinetics	Applying knowledge to new situations, interpreting, solving problems	
2(d)(ii)	Kinetics	Applying knowledge to new situations, interpreting, solving problems	
3(a)(i)	Molecular orbitals	Knowledge and understanding - making statements	
3(a)(ii)	Molecular orbitals	Knowledge and understanding - making statements	
3(a)(iii)	Molecular orbitals	Demonstrating knowledge and understanding of chemistry by providing descriptions and explanations and integrating knowledge	1
3(b)(i)	Synthesis	Knowledge and understanding - making statements	
3(b)(ii)	Synthesis	Applying knowledge to new situations, interpreting, solving problems	
3(b)(iii)	Synthesis	Demonstrating knowledge and understanding of chemistry by providing descriptions and explanations and integrating knowledge	1

Section 2

Question	Area of Course	Question Type	A-type
4(a)	Volumetric analysis	Knowledge and understanding - making statements	
4(b)(i)	Stoichiometric calculations	Applying knowledge to new situations, interpreting, solving problems	
4(b)(ii)	Stoichiometric calculations	Applying knowledge to new situations, interpreting, solving problems	
4(c)	Volumetric analysis	Demonstrating knowledge and understanding of chemistry by providing descriptions and explanations and integrating knowledge	2
5(a)(i)	Transition metals	Applying knowledge to new situations, interpreting, solving problems	
5(a)(ii)	Transition metals	Applying knowledge to new situations, interpreting, solving problems	
5(b)(i)	Gravimetric analysis	Planning or designing experiments	1
5(b)(ii)	Stoichiometric calculations	Applying knowledge to new situations, interpreting, solving problems	
5(c)(i)	Volumetric analysis	Knowledge and understanding - making statements	
5(c)(ii)	Practical skills and techniques	Planning or designing experiments	
6(a)	Experimental determination of structure	Applying knowledge to new situations, interpreting, solving problems	
6(b)(i)	Experimental determination of structure	Processing information (using calculations significant figures and units, where appropriate)	
6(b)(ii)	Experimental determination of structure	Processing information (using calculations significant figures and units, where appropriate)	1
6(c)	Experimental determination of structure	Drawing valid conclusions and giving explanations supported by evidence/justification	1
7(a)	Synthesis	Applying knowledge to new situations, interpreting, solving problems	
7(b)	Synthesis	Applying knowledge to new situations, interpreting, solving problems	
7(c)	Synthesis	Applying knowledge to new situations, interpreting, solving problems	1
7(d)(i)	Synthesis	Planning or designing experiments	
7(d)(ii)	Stoichiometric calculations	Applying knowledge to new situations, interpreting, solving problems	1

Section 2

Question	Area of Course	Question Type	A-type
8(a)	Chemical equilibrium	Applying knowledge to new situations, interpreting, solving problems	
8(b)(i)	Chemical equilibrium	Applying knowledge to new situations, interpreting, solving problems	
8(b)(ii)	Chemical equilibrium	Demonstrating knowledge and understanding of chemistry by providing descriptions and explanations and integrating knowledge	1
8(c)	Chemical equilibrium	Planning or designing experiments	1
9(a)	Pharmaceutical chemistry	Knowledge and understanding - making statements	
9(b)	Pharmaceutical chemistry	Knowledge and understanding - making statements	
9(c)	Stoichiometric calculations	Demonstrating knowledge and understanding of chemistry by providing descriptions and explanations and integrating knowledge	
9(d)	Stereochemistry	Applying knowledge to new situations, interpreting, solving problems	2
10(a)(i)	Non-specific	Processing information (using calculations significant figures and units, where appropriate)	1
10(a)(ii)	Synthesis	Processing information (using calculations significant figures and units, where appropriate)	
10(b)	Non-specific	Evaluating experiments and suggesting improvements	1
11(a)(i)	Chemical equilibrium	Applying knowledge to new situations, interpreting, solving problems	
11(a)(ii)	Chemical equilibrium	Applying knowledge to new situations, interpreting, solving problems	1
11(b)	Atomic orbitals, electronic configurations and the periodic table	Drawing valid conclusions and giving explanations supported by evidence/justification	1

Section 2

Question	Area of Course	Question Type	A-type
12(a)	Synthesis	Applying knowledge to new situations, interpreting, solving problems	
12(b)	Practical skills and techniques	Knowledge and understanding - making statements	
12(c)	Practical skills and techniques	Planning or designing experiments	
12(d)	Synthesis	Knowledge and understanding - making statements	
12(e)	Synthesis	Applying knowledge to new situations, interpreting, solving problems	1
12(f)(i)	Chemical equilibrium, practical skills and techniques	Demonstrating knowledge and understanding of chemistry by providing descriptions and explanations and integrating knowledge; planning or designing an experiment	1
12(f)(ii)	Practical skills and techniques	Planning or designing experiments	
12(g)	Practical skills and techniques	Planning or designing experiments	
12(h)(i)	Practical skills and techniques	Planning or designing experiments	
12(h)(ii)	Practical skills and techniques	Demonstrating knowledge and understanding of chemistry by providing descriptions and explanations and integrating knowledge	1
12(i)	Experimental determination of structure	Drawing valid conclusions and giving explanations supported by evidence/justification	