



*Rewarding Learning*

**ADVANCED**  
**General Certificate of Education**

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## **Chemistry**

**Assessment Unit A2 2**

*assessing*

Analytical, Transition Metals, Electrochemistry  
and Further Organic Chemistry

**[ACH22]**

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## **Assessment**

**MARK  
SCHEME**

## General Marking Instructions

### Introduction

Mark schemes are published to assist teachers and students in their preparation for examinations. Through the mark schemes, teachers and students will be able to see what examiners are looking for in response to questions and exactly where the marks have been awarded. The publishing of the mark schemes may help to show that examiners are not concerned about finding out what a student does not know but rather, with rewarding students for what they do know.

### The Purpose of Mark Schemes

Examination papers are set and revised by teams of examiners and revisers appointed by the Council. The teams of examiners and revisers include experienced teachers who are familiar with the level and standards expected of students in schools and colleges.

The job of the examiners is to set the questions and the mark schemes; and the job of the revisers is to review the questions and mark schemes commenting on a large range of issues about which they must be satisfied before the question papers and mark schemes are finalised.

The questions and the mark schemes are developed in association with each other so that the issues of differentiation and positive achievement can be addressed right from the start. Mark schemes, therefore, are regarded as part of an integral process which begins with the setting of questions and ends with the marking of the examination.

The main purpose of the mark scheme is to provide a uniform basis for the marking process so that all the markers are following exactly the same instructions and making the same judgements in so far as this is possible. Before marking begins, a standardising meeting is held where all the markers are briefed using the mark scheme and samples of the students' work in the form of scripts. Consideration is also given at this stage to any comments on the operational papers received from teachers and their organisations. During this meeting, and up to and including the end of the marking, there is provision for amendments to be made to the mark scheme. The document published represents this final form of the mark scheme.

It is important to recognise that in some cases there may well be other correct responses which are equally acceptable to those published: the mark scheme can only cover those responses which emerged in the examination. There may also be instances where certain judgements may have to be left to the experience of the examiner, for example, where there is no absolute correct response – all teachers will be familiar with making such judgements.

## General marking guidance for GCE Chemistry

### 1. Alternative responses

In general, a solidus (/) used between responses indicates alternative answers or parts of an answer.

When a solidus may be confused with part of the answer (for example as a division sign or with units) “or” may be used to show alternatives.

Example: What is observed when propanone is warmed with Tollens' reagent? [1]  
MS: remains colourless/no change [1]

### 2. Acceptable colours and observations

For the use of a solidus with the colours supplied in the **acceptable colour changes and observations** document, the solidus indicates that one of the responses should be given.

Example: What colour is the flame observed when a flame test is carried out on a sample of sodium chloride? [1]  
MS: yellow/orange [1]

Response	Candidate Response	Marks awarded	Notes
1	yellow	1	Correct response
2	orange	1	Correct response
3	yellow-orange	0	Both responses with a hyphen not credited

In the acceptable colour changes and observations document, where two colours are given with a hyphen between them, this indicates that both colours are required in a response with the hyphen between them.

Example: What is observed when a few drops of sodium hydroxide solution are added to a solution containing  $\text{Cr}^{3+}$  ions? [1]  
MS: green-blue ppt [1]

Response	Candidate Response	Marks awarded	Notes
1	green-blue ppt	1	Correct response
2	blue-green ppt	1	Correct response
3	blue/green ppt	0	Hyphen is required between the colours
4	blue ppt	0	Both colours required with a hyphen
5	green ppt	0	Both colours required with a hyphen

Note that in Booklet A of AS3 and A23, more flexibility is allowed on the marking of colours. A range of colours and shades of those colours will be accepted.

### 3. Brackets in a response

Normal parentheses used in a mark scheme response means that a term is **not required** for the response to be marked correct. However, an incorrect term would lose the mark.

Example: Describe how you would make a salt bridge using paper in the laboratory. [1]  
MS: Soak a strip of filter paper in a (saturated/concentrated) solution of potassium chloride/potassium nitrate [1]

Response	Candidate Response	Marks awarded	Notes
1	soak filter paper in potassium chloride solution	1	Correct response
2	soak a piece of filter paper in dilute potassium nitrate solution	0	Not accepted as dilute is incorrect

### 4. Marking of lists

Where candidates give extra responses, additional correct responses can be ignored.

Additional neutral responses can also be ignored. A neutral response is one which does not have a bearing on the question but is not incorrect.

Additional incorrect responses **cancel out** a correct response to the marking point to which they pertain.

Example: Describe how the presence of chloride ions could be confirmed in a sample of solid sodium chloride. [4]  
MS: dissolve the solid in water/nitric acid [1]  
add silver nitrate solution [1]  
white [1] precipitate [1] [4]

Response	Candidate Response	Marks awarded	Notes
1	Dissolve the solid in nitric acid and add silver nitrate solution and you will get a white precipitate/solution	3	The last mark is not awarded as solution is an incorrect response cancelling out the correct response.
2	Put the solid in water and add silver nitrate and ammonia. You will get a white precipitate.	3	No mention of <b>solution</b> with silver nitrate and ammonia is not completely incorrect but in context of this response it cancels out the second mark as well if they had written solution
3	Add silver nitrate solution and you get a white precipitate/solution	2	First mark not awarded and precipitate mark not awarded as solution would cancel this out

## 5. Marking values where a range is given

Where a numerical range is given, correct responses are any value in the range, the range itself or any other range given which falls within the MS range.

Example: Name the reagents and conditions under which they are used to form the benzenediazonium ion from phenylamine. [2]

MS: sodium nitrite and (dil/conc) hydrochloric acid [1]  
temperature 0 – 10 °C/in ice [1]

Focussing on the range awarded for the second mark.

Response	Candidate Response	Marks awarded	Notes
1	0	1	A single value within the accepted range
2	1	1	A single value within the accepted range
3	5	1	A single value within the accepted range
4	10	1	A single value within the accepted range
5	2.5	1	A single value within the accepted range
6	0–10	1	The accepted range
7	5–10	1	A range given within the accepted range
8	5–15	0	Range given outside the accepted range

## 6. Names of compounds

- Any question which asks you to “name” a chemical expects a correct chemical name and any errors in the name given by a candidate will be a –1 error.
- Where a question asks for an IUPAC name for an organic compound, the answer will require, where appropriate, correct locant numbers, dashes, commas and spaces. Each error is –1.
- The term systematic name is often used in inorganic nomenclature where oxidation states are required, e.g. sodium sulfate(IV). An incorrect oxidation state would be a –1 error.

## 7. Marking equations

Some general points about formulae and equations:

- Equations are usually worth 1 mark if they do not require balancing, however very familiar equations with balancing may only be worth 1 mark and in that case all formulae and balancing must be correct.
- Equations worth 2 marks are marked as [1] for all formulae being correct and [1] for correct balancing. The balancing mark is dependent on the formulae mark and is only considered if all the formulae are correct. If any formula incorrect, no marks are awarded.
- Some more complex structural equations are worth 3 marks. Details of how to mark these questions will be provided in the mark scheme.

## 8. QWC

Quality of written communication is marked using indicative content and a banded mark scheme.

The initial marking is for the indicative content points. The number of indicative content points places a candidate in a specific band. The overall marks awarded should be in that band based on the standard of the written communication.

A typical banded grid from a mark scheme where there would be 8 indicative content points is shown below:

Band	Response	Mark
A	Candidates must use appropriate specialist terms including a minimum of 7 points of indicative content. They use good spelling, punctuation and grammar and the form and style are of a high standard.	[5]–[6]
B	Candidates must use appropriate specialist terms including a minimum of 5 points of indicative content. They use satisfactory spelling, punctuation and grammar and the form and style are of a satisfactory standard.	[3]–[4]
C	Candidates provide a brief and partial response including a minimum of 2 points of indicative content. They use limited spelling, punctuation and grammar and they have made little use of specialist terms. The form and style are of a limited standard.	[1]–[2]
D	Response not worthy of credit.	[0]

[6]

A candidate who provides 5 indicative content points is placed in band B and can be awarded 3 or 4 overall marks (out of 6) for their response based on the spelling, punctuation and grammar.

Generally, the upper mark in a band would be awarded unless the quality of the written communication was very poor (i.e. multiple spelling, punctuation and grammar errors).

## 9. Marking calculations

- The total marks in a calculation are given at the end of the question part on the mark scheme and each error in the calculation is –1 mark.
- Errors in a calculation may be carried forward within part of a calculation. This should be indicated using ECF.
- Where a specific number of significant figures or decimal places is asked for in the question, this should be provided and not following this instruction would be classed as an error.
- The phrase “appropriate number of significant figures” is used where a candidate must make a decision about the number of significant figures they use for their final answer. This will be the lowest number of significant figures in the data provided which is used in the calculation.
- Calculations which use the number in the calculator and arrive at the correct answer (following any instructions regarding significant figures or decimal places) can be awarded full marks.
- A correct numerical answer to a calculation (given to the specified number of significant figures or decimal places or correct appropriate number of significant figures) can be awarded full marks provided that the question does not state that working out must be shown.
- Where appropriate, units would be required with a numerical answer.

## 10. Definitions

- Definitions are provided in the clarification of terms document. Each error/omission in the definition is -1. Correct extra information provided by a candidate would not be penalised.
- Minor errors should not be penalised if they do not change the meaning of the answer given.

## 11. Organic structures

- Structural formulae should generally show the individual groups or atoms bonded to each carbon atom in the main chain or ring structure.  $\text{CH}_3$ ,  $\text{CH}_2$ ,  $\text{CH}$ ,  $\text{OH}$ ,  $\text{NH}_2$ ,  $\text{CN}$ ,  $\text{CHO}$ ,  $\text{CO}$ ,  $\text{COOH}$ ,  $\text{COCl}$ ,  $\text{COO}$ ,  $\text{CONH}_2$  etc do not need to be expanded to show all bonds except where specifically asked for in the question.
- Skeletal formulae must show the angled chain. Functional groups should be clearly shown with all atoms except for carbon atoms.
- Each organic structure is generally worth 1 mark. However more complex structures may be worth more marks.
- Connectivity of atoms in structural formulae should only be penalised based on what is presented in the table.
- Bonds to groups on the left (or right) of a structure should be connected to the correct atom apart from in the case of  $\text{CH}_3$  groups.
- Bonds going vertically to groups should be bonded to the correct atom, however if the bond appears to be close to the required atom, this may be accepted.

Accepted		Not accepted		
$\begin{array}{c}   \\ \text{H}_3\text{C}-\text{C}- \\   \end{array}$		N/A		
$\begin{array}{c}   \\ \text{CH}_3-\text{C}- \\   \end{array}$		N/A		
$\begin{array}{c}   \\ \text{CH}_3\text{CH}_2-\text{C}- \\   \end{array}$		$\begin{array}{c}   \\ \text{CH}_2\text{CH}_3-\text{C}- \\   \end{array}$		
$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{CH}_2\text{CH}_3 \end{array}$		$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{CH}_3\text{CH}_2 \end{array}$		
$\begin{array}{c}   \\ \text{H}_2\text{N}-\text{C}- \\   \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{NH}_2 \end{array}$	$\begin{array}{c}   \\ \text{NH}_2-\text{C}- \\   \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{H}_2\text{N} \end{array}$	
$\begin{array}{c}   \\ \text{HO}-\text{C}- \\   \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{OH} \end{array}$	$\begin{array}{c}   \\ \text{OH}-\text{C}- \\   \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{HO} \end{array}$	
$\begin{array}{c}   \\ \text{NC}-\text{C}- \\   \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{CN} \end{array}$	$\begin{array}{c}   \\ \text{CN}-\text{C}- \\   \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{NC} \end{array}$	
$\begin{array}{c}   \\ \text{OHC}-\text{C}- \\   \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{CHO} \end{array}$	$\begin{array}{c}   \\ \text{CHO}-\text{C}- \\   \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{OHC} \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{CHO} \end{array}$
$\begin{array}{c}   \\ \text{HOOC}-\text{C}- \\   \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{COOH} \end{array}$	$\begin{array}{c}   \\ \text{COOH}-\text{C}- \\   \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{HOOC} \end{array}$	$\begin{array}{c}   \\ -\text{C}- \\   \\ \text{COOH} \end{array}$

## 12. Mechanisms

The following features are required for electrophilic addition, electrophilic substitution, nucleophilic substitution and nucleophilic addition mechanisms:

1. Curly arrows (coming from a bond or the ring of a benzene ring or from a lone pair of electrons)  
When the curly arrow is showing the formation of a bond, it may go to the atom, close to the atom or in the position where the bond would form.
2. Lone pairs of electrons shown as a double dot beside the relative atom/ion.
3. Any charges on the intermediates in the mechanism.
4. Any leaving group shown in the products for substitution mechanisms.

Note that for radical substitution mechanisms the dot may be placed before or after the radical.

## 13. Marking diagrams

- Diagrams of apparatus are again marked in terms of the errors. Each error is -1.
- Diagrams of apparatus are expected to be two-dimensional cross-sectional diagrams of the assembled apparatus with clear labelling and recognisable pieces of apparatus.
- There should be no blockage to the flow of liquids or gases in a diagram of apparatus such as a line across the end of a delivery tube or the exit or entry from a piece of glassware unless intentional such as the valve in a separating funnel.

## 14. Solution/aqueous

- When describing a practical method or test and a solution of a substance is used, the term **solution** is required in the response unless it is in brackets in the mark scheme.
- The term solution is equivalent to aqueous. For example, aqueous sodium hydroxide is the same as sodium hydroxide solution.
- Solution is not required for dilute acids.

**Section A**

- 1 D
- 2 D
- 3 C
- 4 D
- 5 C
- 6 A
- 7 C
- 8 D
- 9 D
- 10 A

[1] for each correct answer

[10]

**Section A**

**AVAILABLE  
MARKS**

10

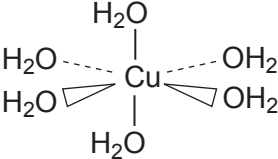
**10**

## Section B

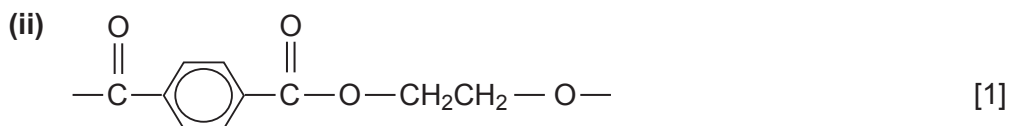
AVAILABLE  
MARKS

- 11 (a) (i) diethylamine/methylpropylamine [1]
- (ii) primary amine has one alkyl group bonded to nitrogen atom and secondary amine has two [1]  
two alkyl groups make the lone pair more available [1] [2]
- (iii) hydrogen bonding between butylamine molecules [1]  
no hydrogen bonding between dimethylethylamine molecules [1]  
greater area of contact between (linear) butylamine molecules than between (branched) dimethylethylamine so greater van der Waals' forces between the molecules [1] [3]
- (iv)  $2\text{CH}_3\text{CH}_2\text{N}(\text{CH}_3)_2 + \text{H}_2\text{SO}_4 \rightarrow (\text{CH}_3\text{CH}_2\text{NH}(\text{CH}_3)_2)_2\text{SO}_4$  [2]
- (b) (i)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$  [1]
- (ii) Reagent A lithium tetrahydridoaluminate(III)/lithium aluminium hydride/lithal [1]  
Reagent B sodium hydroxide [1] [2]
- (iii) butanenitrile [1]
- (iv)  
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_3^+ \text{Br}^- + \text{NaOH} \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2 + \text{NaBr} + \text{H}_2\text{O}$  [1]
- (c) (i)  
 $\text{C}_6\text{H}_5\text{COCl} + \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2 \rightarrow \text{C}_6\text{H}_5\text{CONHCH}_2\text{CH}_2\text{CH}_2\text{CH}_3 + \text{HCl}$  [1]
- (ii) determine its melting point [1]  
compare with known values in data book [1] [2]
- (d) (i) three carbons directly attached to the same carbon as the –OH group [1]
- (ii) primary [1]  
one carbon directly attached to the nitrogen atom/presence of  $\text{NH}_2$  group [1] [2]

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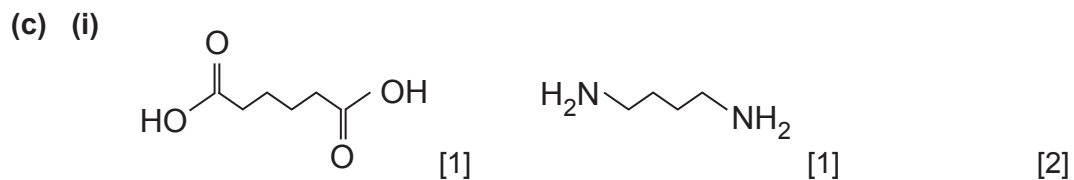
- 12 (a) (i)** Cu  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}/1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$  [1]  
 Cu<sup>2+</sup>  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$  [1]
- (ii)**
- 
- [1]
- hexaaquacopper(II) [1] [2]
- (iii)** blue  
 green  
 colourless [2]
- (iv)** an element which forms at least one stable ion with a partially filled d-subshell [2]
- (v)** Zn<sup>2+</sup>/the only stable ion does not have a partially filled d subshell [1]
- (b) (i)**  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4] + 2\text{H}_2\text{O}$  [1]
- (ii)**  $[\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4] + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 2\text{H}_2\text{O} + 2\text{OH}^-$  [2]
- (c) (i)** blue [1]
- (ii)**  $[\text{Ni}(\text{NH}_3)_6]^{2+} + 3\text{en} \rightarrow [\text{Ni}(\text{en})_3]^{2+} + 6\text{NH}_3$   
 or  
 $[\text{Ni}(\text{NH}_3)_6]^{2+} + 3\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2 \rightarrow [\text{Ni}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]^{2+} + 6\text{NH}_3$  [2]
- (iii)** breaking 6 Ni–N bonds forming 6 Ni–N bonds/same number and type of bonds broken and formed [1]  
 energy involved in breaking and forming bonds is approximately equal [1] [2]
- (iv)** 7 moles to 4 moles [1]  
 $\Delta S < 0$ /decrease in entropy [1]  
 $\Delta G > 0$  [1] max [2]
- (v)** a ligand which uses many lone pairs of electrons to form more than two co-ordinate bonds with a central metal atom or ion in a complex. [2]
- (vi)**  $[\text{Ni}(\text{en})_3]^{2+} + \text{edta}^{4-} \rightarrow [\text{Ni}(\text{edta})]^{2-} + 3\text{en}$   
 or  
 $[\text{Ni}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]^{2+} + \text{edta}^{4-} \rightarrow [\text{Ni}(\text{edta})]^{2-} + 3\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$  [2]

13 (a) (i) polyester [1]



(b) (i) polyamide [1]

(ii) the amide link [1]  
can be hydrolysed by the action of microorganisms [1] [2]



(ii) hexanedioic acid [1] butanediamine/1,4-diaminobutane/butane-1,4-diamine [1] [2]

(d) (i) 5-aminopentanoic acid [1]

(ii) X and Y can form hydrogen bonds (between the molecules) [1]  
as they contain N-H and C=O groups [1] [2]

(iii) same (molecular) formula [1] different structure [1] [2]

AVAILABLE  
MARKS

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14 (a) propanoyl chloride [1]    2-aminopropane [1]    [2]

(b)  $\text{CH}_3\text{CH}_2\text{CO}^+$     [1]

(c) **Indicative content**

**Integration:**

- chemically equivalent hydrogens are in a 3:2:1:1:6 ratio

**Spin-spin splitting:**

For A

- $\text{CH}_3$  appears as a triplet
- $\text{CH}_2$  appears as a quartet

For B

- 2  $\text{CH}_3$  appears as a doublet

**Chemical shift:**

- N–H highest chemical shift
- at 5.5–8.5 ppm

Band	Response	Mark
A	Candidates must use appropriate specialist terms using a minimum of 5 points of indicative content. They must use good spelling, punctuation and grammar and the form and style are of an excellent standard.	[5]–[6]
B	Candidates must use appropriate specialist terms using a minimum of 3 points of indicative content. They must use satisfactory spelling, punctuation and grammar and the form and style are of a good standard.	[3]–[4]
C	Candidates must use a minimum of 2 points of indicative content. They use limited correct spelling, punctuation and grammar and the form and style are of a basic standard.	[1]–[2]
D	Response not worthy of credit	[0]

[6]

AVAILABLE  
MARKS

9

- 15 (a) (i)** the potential difference measured when a half-cell is connected to the standard hydrogen electrode under standard conditions. [2]
- (ii)** +1.51V [1]
- (iii)**  $\text{S}_2\text{O}_8^{2-}$  [1]
- (iv)**  $\text{Mn}^{2+}$  [1]
- (v)**  $\text{S}_2\text{O}_8^{2-} + 2\text{e}^- \rightarrow 2\text{SO}_4^{2-}$  [1]  
Reduction – gain of electrons [1] [2]
- (vi)**  $\text{Mn}^{2+} + 4\text{H}_2\text{O} \rightarrow \text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^-$  [1]  
Oxidation – loss of electrons [1] [2]
- (vii)**  $2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{S}_2\text{O}_8^{2-} \rightarrow 2\text{MnO}_4^- + 16\text{H}^+ + 10\text{SO}_4^{2-}$  [1]
- (b) (i)** +2.90V [1]
- (ii)**  $\text{LiMnO}_2 \rightarrow \text{Li} + \text{MnO}_2$  [2]
- (c) (i)** (the water produced is) non-polluting [1]
- (ii)** hydrogen production may use fossil fuels which leads to global warming/uses resources/uses toxic chemicals in manufacture/flammability of hydrogen/storage of hydrogen or other suitable answer [1]
- (iii)** limit to travel distance/recharging is time consuming [1]  
any reference to environmental issues [1] [2]

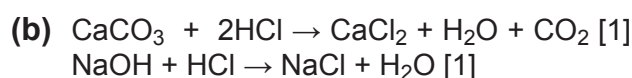
AVAILABLE  
MARKS

17

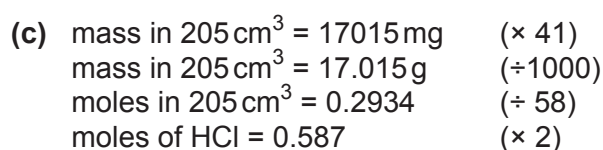
- 16 (a)
- weigh the tablet
  - add excess hydrochloric acid
  - titrate the excess hydrochloric acid with a standard solution of sodium hydroxide/alkali
  - using phenolphthalein as an indicator
  - until the indicator changes from colourless to pink

Band	Response	Mark
A	Candidates must use appropriate specialist terms using a minimum of 5 points of indicative content. They must use good spelling, punctuation and grammar and the form and style are of an excellent standard.	[5]–[6]
B	Candidates must use appropriate specialist terms using a minimum of 3 points of indicative content. They must use satisfactory spelling, punctuation and grammar and the form and style are of a good standard.	[3]–[4]
C	Candidates must use a minimum of 2 points of indicative content. They use limited correct spelling, punctuation and grammar and the form and style are of a basic standard.	[1]–[2]
D	Response not worthy of credit	[0]

[6]

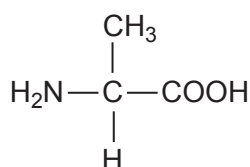


[2]



[3]

(d) (i) 2-aminopropanoic acid



[2]

or any amino acid apart from glycine

(ii) exist as dipolar ions/zwitterions [1]  
held together by strong electrostatic attractions/ionic bonding [1] [2]

(e) changes the tertiary structure/disrupts ionic interactions [1]  
alters the shape of the active site [1]  
substrate cannot (induce a) fit [1]

[3]

AVAILABLE  
MARKS

18

Section B

100

Total

110