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General Certificate of Education
2025

Centre Number

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Candidate Number

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Chemistry

Assessment Unit A2 2

assessing

Analytical, Transition Metals,
Electrochemistry and Further
Organic Chemistry



[ACH24]

ACH24

WEDNESDAY 11 JUNE, AFTERNOON

TIME

2 hours.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

In **Section A**, answer each question by circling the appropriate letter below the question.

In **Section B**, you must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete questions in black ink only and use a dark HB pencil for drawings and graphs.

Do not write with a gel pen.

Answer **all fifteen** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 110.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

You may use a scientific calculator.

Quality of written communication will be assessed in Questions **12(a)** and **14(c)**.

A Data Leaflet, which includes a Periodic Table of the Elements, is included in this question paper.

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Section A

For each of the following questions, only **one** of the lettered responses (A – D) is correct.

Select the correct response for each question by circling the appropriate letter below the question.

1 Which one of the following will **not** be present in the mass spectrum of ethanoic anhydride, $(\text{CH}_3\text{CO})_2\text{O}$?

- A a fragment ion peak at $m/z = 11$
- B a fragment ion peak at $m/z = 43$
- C a molecular ion peak at $m/z = 102$
- D an $M+1$ peak at $m/z = 103$

Answer: A B C D [1]

2 Which one of the following describes the peaks in the nmr spectrum of ethyl ethanoate?

A	doublet integration 3	quartet integration 2	triplet integration 3
B	quartet integration 3	doublet integration 2	quartet integration 3
C	singlet integration 3	quartet integration 2	triplet integration 3
D	singlet integration 3	quartet integration 3	triplet integration 2

Answer: A B C D [1]



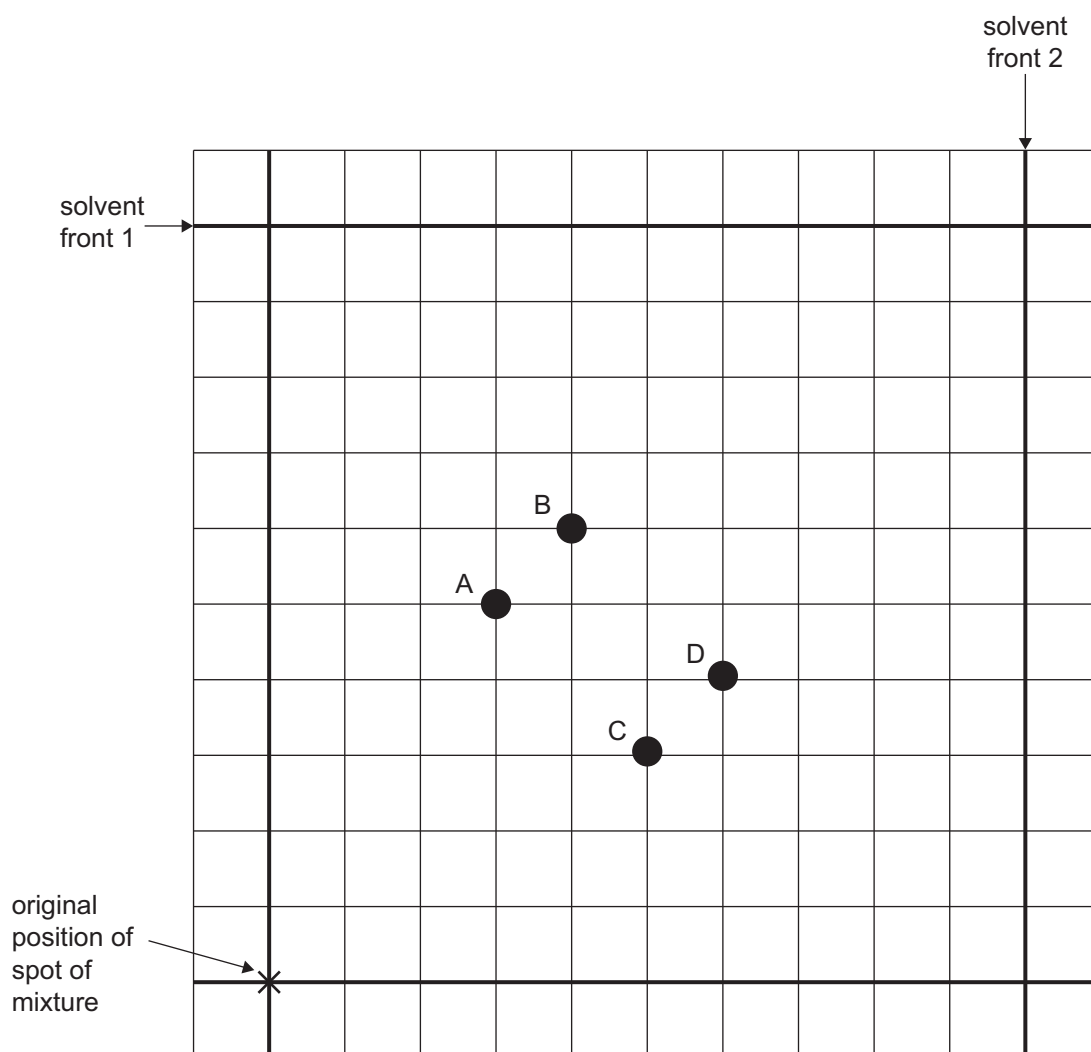
- 5 Which one of the following gives the molecular formula of propanamide and of the organic product obtained when propanamide reacts with phosphorus pentoxide?

propanamide	organic product
A C_3H_7NO	C_3H_5N
B C_3H_7NO	C_3H_4O
C C_4H_9NO	C_4H_7N
D $C_4H_{11}N$	C_4H_8

Answer: A B C D [1]



6 A two-way chromatogram of a mixture containing four amino acids (labelled A, B, C and D) is shown below.



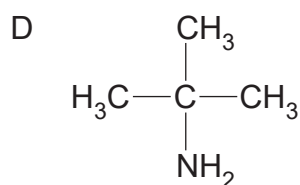
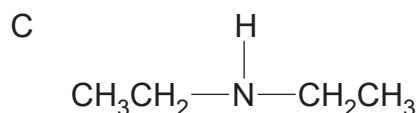
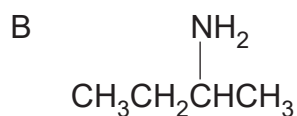
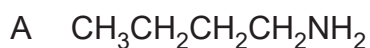
Which one of the spots (A, B, C or D) has an R_f value of 0.6 in solvent 1 and 0.4 in solvent 2?

Answer: A B C D [1]

[Turn over



7 Which one of the following is the strongest base?



Answer: A B C D [1]

8 An excess of sodium hydroxide solution was added to crushed aspirin tablets. The solution was heated and made up to 250 cm^3 in a volumetric flask using deionised water.

Portions of the resulting solution were titrated against hydrochloric acid.

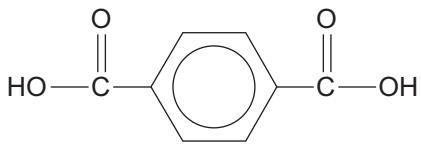
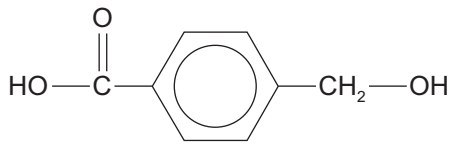
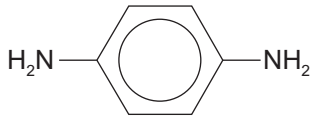
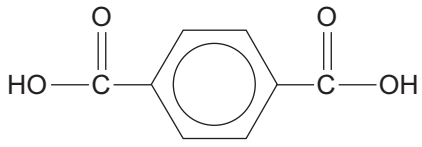

Which one of the following gives a suitable indicator and the colour change at the end point of the titration?

- | | | |
|---|-----------------|--------------------|
| A | methyl orange | red to yellow |
| B | methyl orange | pink to colourless |
| C | phenolphthalein | colourless to pink |
| D | phenolphthalein | pink to colourless |

Answer: A B C D [1]

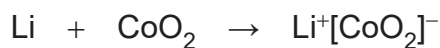


9 Which one of the following pairs of monomers could **not** be used to produce a condensation polymer?

A		$\text{HOCH}_2\text{CH}_2\text{OH}$
B		$\text{HO}-\text{C}(=\text{O})-\text{CH}_2-\text{OH}$
C		
D		$\text{HOCH}_2\text{CH}_2\text{OH}$

Answer: A B C D [1]

10 The overall equation for the reaction which occurs when a lithium ion cell discharges is:



Which one of the following is correct?

- A The oxidation state of lithium changes from +1 to 0
- B The oxidation state of cobalt changes from +4 to +3
- C Lithium is oxidised at the positive electrode
- D Lithium is reduced at the negative electrode

Answer: A B C D [1]

[Turn over



Section B

Answer all **five** questions in this section.

11 Copper, cobalt and nickel are transition metals.

(a) A sample of copper(II) sulfate was dissolved in deionised water. The resulting solution was divided into two separate portions.

(i) A few drops of aqueous ammonia were added to the first portion of copper(II) sulfate solution and a precipitate formed. Give the formula and colour of the precipitate.

Formula: _____

Colour: _____ [2]

(ii) When an excess of concentrated ammonia solution was then added, the precipitate disappeared. Write an ionic equation for the reaction which occurs when the precipitate disappears and give the final colour of the solution.

Ionic equation:

Final colour of solution: _____ [3]

(b) When an excess of concentrated hydrochloric acid was added to the second portion of copper(II) sulfate solution, a colour change was observed.

(i) Write an ionic equation for the addition of concentrated hydrochloric acid to the copper(II) sulfate solution.

_____ [2]

(ii) State the colour change observed in this reaction.

From _____ to _____ [1]



- (c) Complete the table below giving the co-ordination number and shape of each complex ion.

Complex ion	Co-ordination number	Shape
$[\text{Co}(\text{H}_2\text{O})_6]^{2+}$		
$[\text{CoCl}_4]^{2-}$		

[2]

- (d) When an excess of 1,2-diaminoethane ($\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$) was added to an aqueous solution of nickel(II) sulfate, a purple complex ion was formed.

State the initial colour of the nickel(II) sulfate solution and draw the three dimensional structure of the purple complex ion which formed.

Initial colour of solution: _____

Three dimensional structure of complex ion:

[3]

[Turn over



- (e) (i) In the table below, [Ar] is used to represent the electronic configuration of an atom of argon ($1s^2 2s^2 2p^6 3s^2 3p^6$).

Complete the electronic configurations in the table below. The electronic configuration of a vanadium atom has been given.

Atom	Electronic Configuration	Ion	Electronic Configuration
V	[Ar] $3d^3 4s^2$	V^{3+}	[Ar]
Cr	[Ar]	Cr^{3+}	[Ar]
Cu	[Ar]	Cu^{2+}	[Ar]
Zn	[Ar]	Zn^{2+}	[Ar]

[4]

- (ii) Define the term **transition metal**.

[1]



(b) A standard solution of ethanedioic acid was prepared by dissolving 3.30 g of ethanedioic acid dihydrate, $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$, in deionised water and making the resulting solution up to 250 cm^3 in a volumetric flask.

20.0 cm^3 of this standard solution of ethanedioic acid were titrated against acidified potassium manganate(VII) solution. 16.0 cm^3 were required.

(i) Define the term **standard solution**.

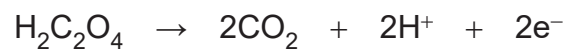
_____ [1]

(ii) Calculate the concentration of the standard solution of ethanedioic acid in mol dm^{-3} . Give your answer to 3 significant figures.

Answer _____ mol dm^{-3} [2]



- (iii) In this titration, the ethanedioic acid is oxidised as shown in the half-equation below.



Write a half-equation for the reduction of manganate(VII) ions. Combine the half-equations to give an overall redox equation.

Half-equation:

Overall redox equation:

[2]

- (iv) Calculate the concentration, in mol dm^{-3} , of the potassium manganate(VII) solution. Give your answer to 3 significant figures.

Answer _____ mol dm^{-3} [3]

[Turn over



13 Butylamine, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$, and phenylamine, $\text{C}_6\text{H}_5\text{NH}_2$, are both primary amines. Butylamine is a primary aliphatic amine whereas phenylamine is a primary aromatic amine.

(a) Butylamine may be produced in a two-step synthesis from 1-bromopropane. Compound X is a nitrile.



(i) Name a reagent required for Step 1 and classify the type of reaction which occurs.

Reagent: _____

Type of reaction: _____ [2]

(ii) Draw the structural formula of Compound X, showing all bonds, and state its IUPAC name.

IUPAC name: _____ [2]

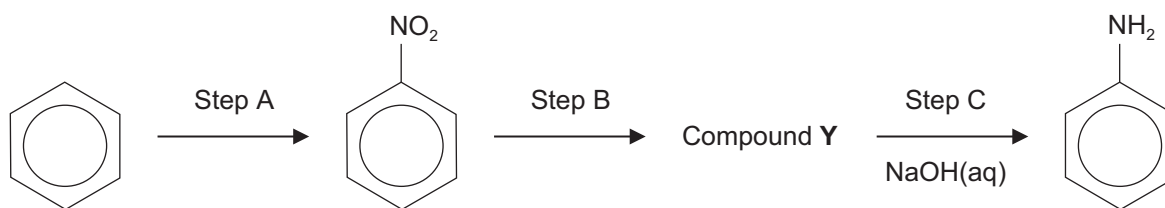
(iii) Identify the reagent required for Step 2 and classify the type of reaction which occurs.

Reagent: _____

Type of reaction: _____ [2]



(b) Phenylamine may be produced, in a three-step synthesis, from benzene.



(i) Name the organic product of Step A.

_____ [1]

(ii) Name the two reagents required for Step B.

1. _____

2. _____ [2]

(iii) Classify the type of reaction which occurs in Step B.

_____ [1]

(iv) Draw the structure and state the name of Compound Y.

Name: _____ [2]

(v) Suggest why sodium hydroxide solution is added in Step C.

_____ [1]

[Turn over



(c) Butylamine and phenylamine both react with nitrous acid. Nitrous acid is prepared in situ by the reaction of sodium nitrite and hydrochloric acid.

(i) What is the systematic name of sodium nitrite?

_____ [1]

(ii) Write an equation to show the formation of nitrous acid in situ.

_____ [1]

(iii) Write an equation for the reaction of butylamine with nitrous acid.

_____ [1]

(iv) Name the organic product formed when phenylamine reacts with sodium nitrite and hydrochloric acid at a temperature less than 5°C.

_____ [1]



(v) When treated with an alkaline solution of phenol, the product named in (c)(iv) reacts to form a brightly coloured organic compound. Draw the structure of this brightly coloured organic compound. Circle and name the link formed in this compound.

Name of link: _____ [3]

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[Turn over



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(d) 1,2-diaminoethane is soluble in water, acts as a Brønsted–Lowry base and reacts with an excess of ethanoyl chloride.

(i) Draw a diagram to show a hydrogen bond between one molecule of 1,2-diaminoethane and one molecule of water. Label the hydrogen bond and include all relevant lone pairs and partial charges.

[2]

(ii) Write an equation for the reaction of 1,2-diaminoethane with an excess of nitric acid.

[1]



(iii) Using skeletal formulae, write an equation for the reaction of 1,2-diaminoethane with an excess of ethanoyl chloride.

[2]

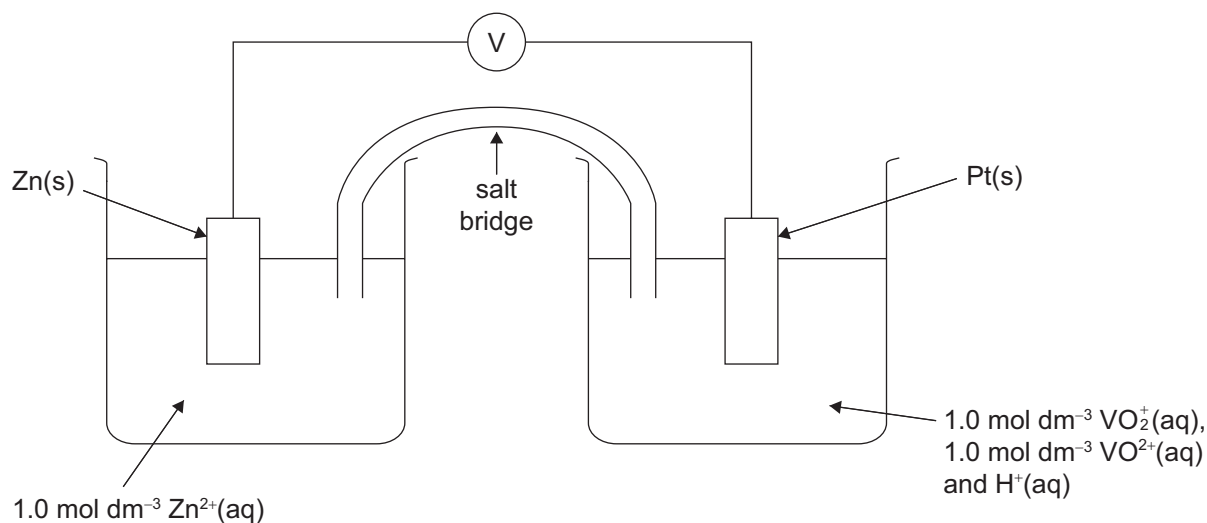
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- 14 The following electrochemical cell was set up, under standard conditions, as part of an investigation into the oxidation states of vanadium. The reading on the voltmeter was +1.76V.



The standard electrode potential of the half-cell on the left is given below. The value for the half-cell on the right is to be calculated.

Half-equation	Standard electrode potential E^\ominus /V
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	to be calculated

- (a) (i) Define the term **standard electrode potential**.

[1]

- (ii) Write the conventional representation for this electrochemical cell. Include state symbols.

[2]



(iii) Calculate the standard electrode potential of the half-cell on the right of the electrochemical cell.

Answer _____ V [1]

(b) The two half-cells are connected without the voltmeter.

(i) Write an ionic equation to represent the overall cell reaction.

_____ [1]

(ii) Identify the oxidising agent in the reaction in (b)(i).

_____ [1]

(iii) State the colour of the following aqueous ions.

$\text{VO}_2^+(\text{aq})$: _____

$\text{VO}^{2+}(\text{aq})$: _____ [2]

[Turn over



15 Amino acids are the building blocks of dipeptides, tripeptides and polypeptides. Glycine, $\text{H}_2\text{NCH}_2\text{COOH}$, and alanine, $\text{H}_2\text{NCH}(\text{CH}_3)\text{COOH}$, are both amino acids.

(a) (i) State the IUPAC name of alanine.

_____ [1]

(ii) Explain why glycine is optically inactive.

_____ [1]

(iii) Draw the three dimensional representations of the optical isomers of alanine.

[2]

[Turn over

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(b) Propanoic acid and glycine have similar relative molecular masses. Propanoic acid exists as a liquid at room temperature and pressure. It has a melting point of -21°C . Glycine exists as a solid at room temperature with a melting point of 233°C . Explain why glycine has a higher melting point than propanoic acid.

[3]

(c) Draw the structures of glycine at pH 1 and pH 12.

pH 1



pH 12

[2]



(d) Two molecules of alanine and one molecule of glycine can combine to form three different tripeptides, all of which have the same molecular formula.

(i) What term is used for molecules which have the same molecular formula but have different structural formulae?

_____ [1]

(ii) Classify the type of reaction which occurs when the three amino acid molecules combine to form a tripeptide.

_____ [1]

(iii) Draw the structure of one tripeptide formed from two molecules of alanine and one molecule of glycine. Circle a peptide link.

[3]

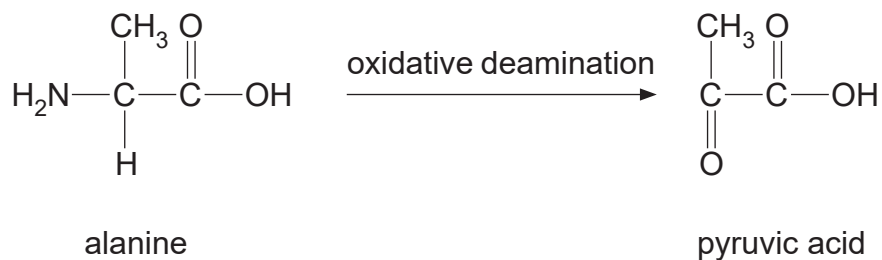
(iv) Classify the type of reaction which would convert the tripeptide back into amino acids.

_____ [1]

[Turn over



- (e) The human body converts excess amino acids into more useful molecules by a process of oxidative deamination using oxygen. Ammonia is the waste product. Oxidative deamination of alanine produces pyruvic acid.

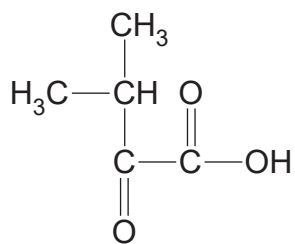


- (i) Write an equation for the oxidative deamination reaction in which alanine reacts with oxygen forming pyruvic acid and ammonia.

[2]



(ii) Oxidative deamination of another amino acid produces compound **Z** shown below.



compound **Z**

Complete the table below giving the mass spectrum data and the nmr spectroscopy data for compound **Z**.

mass spectrum data	
m/z value of molecular ion peak	
nmr spectroscopy data	
number of environments of chemically equivalent hydrogen atoms	
peak integration ratio (from highest chemical shift to lowest)	

[4]

[Turn over



- (iii) The high resolution nmr spectrum of compound **Z** contains a doublet and a singlet. Identify the hydrogen atoms responsible for these peaks and explain the spin-spin splitting patterns.

Doublet: _____

Singlet: _____

_____ [4]

- (iv) Peaks occur at m/z values of 43 and 45 in the mass spectrum of compound **Z**. Identify the fragment ions which cause these peaks.

43 _____

45 _____ [2]

- (v) Draw the structure of the amino acid from which compound **Z** was formed by oxidative deamination and state its IUPAC name.

IUPAC name: _____ [2]

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General Information

1 tonne = 10^6 g

1 metre = 10^9 nm

One mole of any gas at 293 K and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm³

Avogadro Constant = 6.02×10^{23} mol⁻¹

Planck Constant = 6.63×10^{-34} Js

Specific Heat Capacity of water = $4.2 \text{ J g}^{-1} \text{ K}^{-1}$

Speed of Light = $3 \times 10^8 \text{ ms}^{-1}$



Characteristic absorptions in IR spectroscopy

Wavenumber/cm ⁻¹	Bond	Compound
550–850	C–X (X = Cl, Br, I)	Haloalkanes
750–1100	C–C	Alkanes, alkyl groups
1000–1300	C–O	Alcohols, esters, carboxylic acids
1450–1650	C=C	Arenes
1600–1700	C=C	Alkenes
1650–1800	C=O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200–2300	C≡N	Nitriles
2500–3200	O–H	Carboxylic acids
2750–2850	C–H	Aldehydes
2850–3000	C–H	Alkanes, alkyl groups, alkenes, arenes
3200–3600	O–H	Alcohols
3300–3500	N–H	Amines, amides

Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	Structure	
0.5–2.0	–CH	Saturated alkanes
0.5–5.5	–OH	Alcohols
1.0–3.0	–NH	Amines
2.0–3.0	–CO–CH	Ketones
	–N–CH	Amines
	C ₆ H ₅ –CH	Arene (aliphatic on ring)
2.0–4.0	X–CH	X = Cl or Br (3.0–4.0) X = I (2.0–3.0)
4.5–6.0	–C=CH	Alkenes
5.5–8.5	RCONH	Amides
6.0–8.0	–C ₆ H ₅	Arenes (on ring)
9.0–10.0	–CHO	Aldehydes
10.0–12.0	–COOH	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

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COUNCIL FOR THE CURRICULUM, EXAMINATIONS AND ASSESSMENT

29 Clarendon Road, Clarendon Dock, Belfast BT1 3BG

Tel: +44 (0)28 9026 1200 Fax: +44 (0)28 9026 1234

Email: info@ccea.org.uk Web: www.ccea.org.uk



Data Leaflet

Including the Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and
Advanced Level Examinations

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations

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