



Rewarding Learning

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General Certificate of Education
2024

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

MONDAY 10 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.

Answer **all sixteen** questions in **Sections A and 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 in black ink only. **Do not write with a gel pen or a pencil.**

INFORMATION FOR CANDIDATES

The total mark for this paper is 110.

Quality of written communication will be assessed in Questions **13(d)(ii)** and **16(f)**.

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

A Periodic Table of Elements, containing some data, is included with this question paper.

14028



32ACH2401

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 and write the appropriate letter in the space provided.

1 Which one of the following reagents is used to convert propanamide to propanenitrile?

- A KCN
- B LiAlH_4
- C PCl_5
- D P_4O_{10}

Answer _____ [1]

2 Which one of the following is **not** a condition when the standard electrode potential of an electrochemical half-cell is measured?

- A 1 mol dm^{-3} concentration
- B 298 K temperature
- C 100 kPa gas pressure
- D 1 mole of each metal electrode

Answer _____ [1]



3 Which one of the following is the term used to describe the removal of ions, by formation of a complex, so they are no longer available for reaction?

- A coupling
- B dehydration
- C induced fit
- D sequestering

Answer _____ [1]

4 Which one of the following contains an element with the same oxidation state as vanadium in NH_4VO_3 ?

- A $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$
- B K_2MnO_4
- C LiAlH_4
- D NaBrO_3

Answer _____ [1]



5 The table below gives the standard electrode potentials of three half-cells.

Half-cell	E^\ominus / V
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{V}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+0.32
$\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+1.00

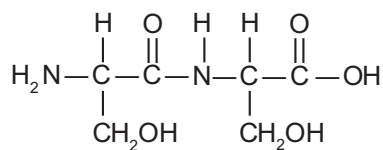
Which one of the following statements is correct?

- A V^{3+} ions are stronger reducing agents than H_2
- B V^{3+} ions will react with H^+ ions
- C VO_2^+ ions are stronger oxidising agents than VO^{2+} ions
- D VO^{2+} ions undergo disproportionation

Answer _____ [1]

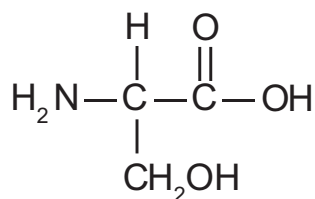


6 The dipeptide formed from the amino acid serine is shown below.

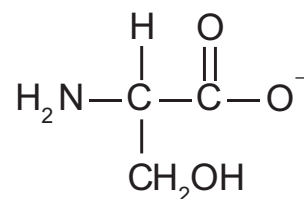


The dipeptide was heated with aqueous hydroxide ions until no further change took place. Which one of the following products was formed?

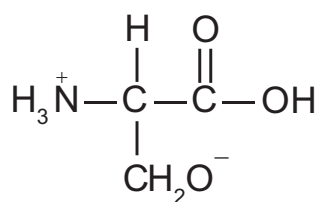
A



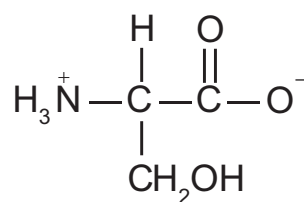
B



C



D



Answer _____ [1]

7 Which one of the following chromatography techniques does **not** require a developing agent or ultraviolet light when analysing a mixture of amino acids?

- A GLC
- B Paper chromatography
- C TLC
- D Two-way paper chromatography

Answer _____ [1]

[Turn over



8 A 1.00 g indigestion tablet containing calcium carbonate is added to 100 cm³ of 0.2 mol dm⁻³ hydrochloric acid. The excess acid was neutralised with 24.6 cm³ of 0.1 mol dm⁻³ sodium hydroxide solution. Which one of the following is the percentage of calcium carbonate in the tablet?

- A 12%
- B 23%
- C 32%
- D 88%

Answer _____ [1]

9 Which one of the following hydroxide precipitates dissolves upon addition of excess sodium hydroxide solution?

- A Co(OH)₂
- B Cr(OH)₃
- C Cu(OH)₂
- D Fe(OH)₃

Answer _____ [1]

10 Which one of the following statements about Pt(NH₃)₂Cl₂ is **not** correct?

- A It contains uncharged ligands
- B It exhibits geometric isomerism
- C It has an overall charge of 2+
- D It is square planar

Answer _____ [1]





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
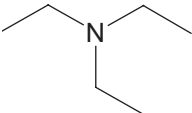
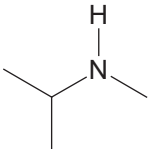
32ACH2407

Section B

Answer **all six** questions in this section

11 Amines are nitrogen containing organic compounds.

(a) (i) Complete the following table.

Skeletal formula	Molecular formula	Classification
	C_3H_9N	
		Tertiary
	C_3H_9N	Secondary
		

[5]



- (ii) The identity of the two C_3H_9N isomers from the table in (a)(i) may be confirmed using ethanoyl chloride, which is added separately to each isomer. Outline the subsequent practical steps that need to be taken to separate, purify and identify each isomer from the products formed.

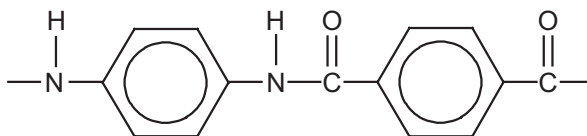
[4]

- (iii) Explain why secondary aliphatic amines are more basic than primary aliphatic amines.

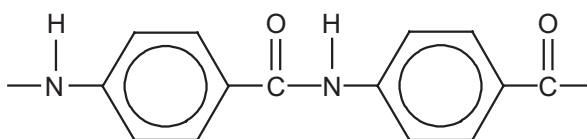
[1]



(b) Amines can be used to form polyamide polymers. The repeating unit of two isomeric polymers are shown below.



Polymer A



Polymer B

(i) Explain why the two polymers are described as isomeric.

_____ [1]

(ii) Name the two monomers used to form Polymer A.

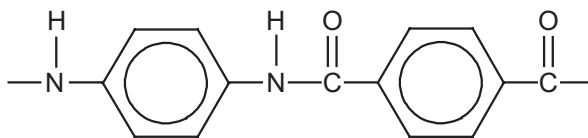
_____ [2]

(iii) Name the single monomer used to form Polymer B.

_____ [1]



(iv) Circle the amide group in Polymer A, below.



[1]

(c) Phenylamine is used to form azo dyes.

(i) Draw the structure of the azo dye formed from the reaction of phenylamine and benzene diazonium chloride.

[2]

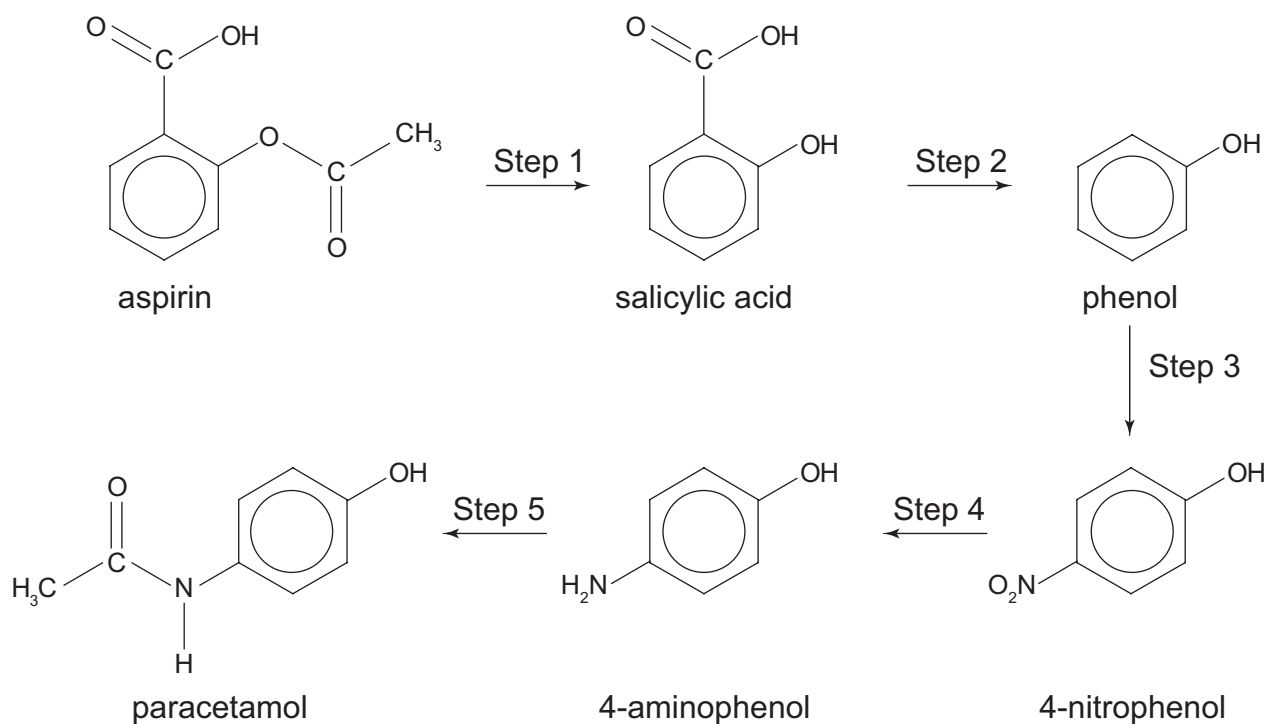
(ii) Explain why azo dyes are coloured.

[3]

[Turn over



12 The reaction scheme shown below can be used to convert aspirin to paracetamol.



(a) State the type of reaction occurring in Step 1 and name a suitable reagent for the reaction.

_____ [2]

(b) A gas is formed in Step 2. Suggest the name of the gas.

_____ [1]



(c) Write an equation for the reaction occurring in Step 3.

_____ [2]

(d) (i) Tin is used in Step 4. Suggest why it is incorrect to describe tin as a catalyst in Step 4.

_____ [1]

(ii) State two other reagents required to carry out the conversion in Step 4.

_____ [2]

(e) 4-aminophenol reacts with ethanoic anhydride in Step 5 to form paracetamol. Write an equation for this reaction.

_____ [2]

[Turn over



- 13 Simple organic compounds, such as the compounds (**A** to **D**) shown below, can be distinguished from each other by mass spectrometry and nmr spectroscopy.

A	B	C	D
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$	$(\text{CH}_3)_2\text{CHCHO}$	$\text{CH}_3\text{COCH}_2\text{CH}_3$	$\text{CH}_3\text{COOCH}_2\text{CH}_3$

- (a) One of the compounds has a molecular ion peak at a higher m/z value than the others in its mass spectrum.

- (i) Define the term **molecular ion peak**.

_____ [1]

- (ii) State and explain which compound (**A**, **B**, **C** or **D**) has the molecular ion peak with the highest m/z value.

_____ [1]

- (b) The fragment ions produced by the loss of the functional group will give rise to peaks at $m/z = 43$ in the mass spectra of compounds **A** and **B**. The peak at $m/z = 43$ in the mass spectrum of compound **B** is the peak of highest abundance.

- (i) State the term used to describe the peak of highest abundance in a mass spectrum.

_____ [1]



(ii) Draw the structures of the fragment ions which give rise to the peaks at $m/z = 43$ in the mass spectra of compounds **A** and **B**.

A

B

[2]

(iii) Suggest another fragment ion which could give rise to the peak at $m/z = 43$ in the mass spectrum of compound **A**.

[1]



- (c) The nmr spectra of compounds **A** and **B** can be used to distinguish between the two compounds.



- (i) State the number of environments of chemically equivalent hydrogen atoms in compound **A** and compound **B**.

A _____

B _____ [2]

- (ii) The nmr spectra of compounds **A** and **B** both have a signal at a chemical shift value between 9.0 and 10.0 ppm. Identify the hydrogen responsible for the signal in each spectrum.

_____ [1]

- (iii) Explain why the signal at the chemical shift value between 9.0 and 10.0 ppm in the nmr spectrum of compound **A** is a triplet whereas the signal at chemical shift value between 9.0 and 10.0 ppm in the spectrum of compound **B** is a doublet.

_____ [2]





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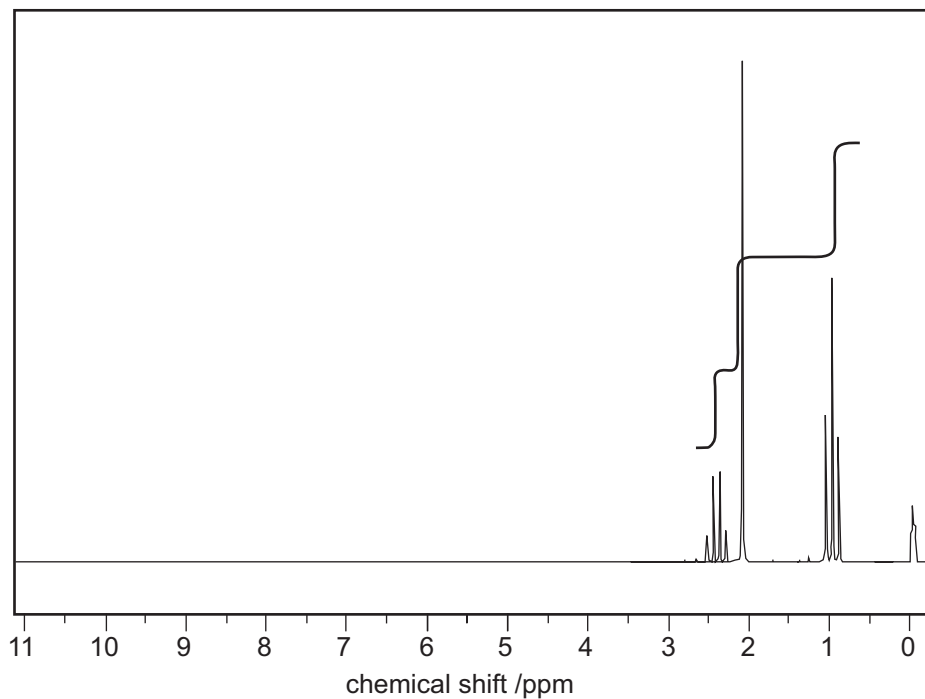
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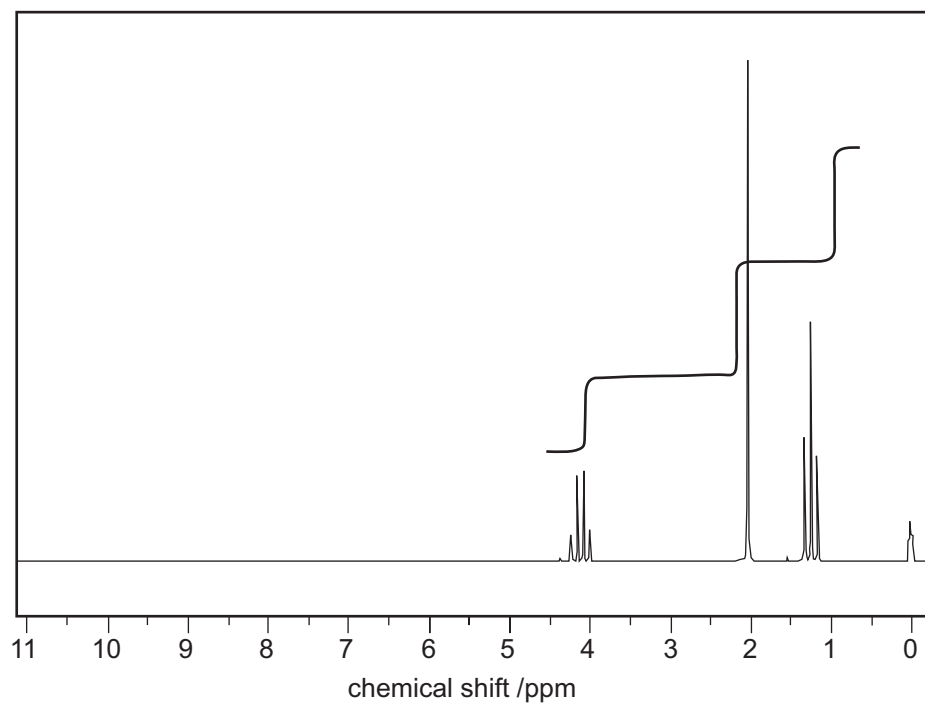
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(d) The nmr spectra of compounds **C** and **D** are shown below.

Compound C



Compound D



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- (i) Name the compound responsible for the peak at a chemical shift of 0 ppm in both spectra and state two reasons why it is used.

[3]

- (ii) The nmr spectra for compounds **C** and **D** are very similar. Describe the similarities and state and explain the main difference in the two spectra in terms of chemical shift, integration ratios and spin-spin splitting patterns.

In this question you will be assessed on using your written communication skills including the use of specialist scientific terms.

[6]

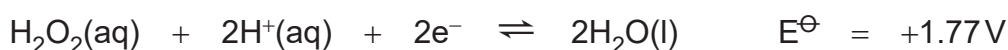


14 Standard electrode potentials can be used to predict the feasibility of a reaction.

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

[2]

(b) Hydrogen peroxide decomposes in a disproportionation reaction. The two half-cells involved in this reaction are given below.



(i) Write the equation for the decomposition of hydrogen peroxide.

[1]

(ii) Define the term **emf**.

[1]

(iii) Calculate the emf of the cell set up from the two half-cells above and use it to explain why the decomposition of hydrogen peroxide is feasible.

[2]

(iv) Suggest why hydrogen peroxide may not decompose under standard conditions despite the decomposition being feasible.

[1]



(c) The standard electrode potentials of a number of half-cells are shown below.

Half-cell	E^\ominus / V
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	+1.36
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51
$\text{Ce}^{4+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ce}^{3+}(\text{aq})$	+1.70
$\text{O}_3(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$	+2.08

(i) Acidified manganate(VII) ions can act as an oxidising agent. Write a redox equation to explain why solutions of manganate(VII) ions should not be acidified with hydrochloric acid.

[3]

(ii) Using the standard electrode potentials above, write the conventional cell representation for a cell which includes the Cl_2/Cl^- half-cell and has an emf of +0.34 V.

[3]

[Turn over



15 Sodium dichromate(VI), $\text{Na}_2\text{Cr}_2\text{O}_7$, is an orange solid which is produced on a large scale from ores containing chromium(III) oxide. An acidified solution of dichromate(VI) ions can act as an oxidising agent.

(a) Chromium(III) oxide is heated with sodium carbonate and oxygen to produce sodium chromate(VI), Na_2CrO_4 , and carbon dioxide.

Write an equation for this reaction.

_____ [2]

(b) The purity of a sample of sodium dichromate(VI) can be determined by titration. 1.0 g of an impure sample of sodium dichromate(VI) was dissolved in an excess of dilute sulfuric acid and the solution made up to 250 cm^3 with deionised water in a volumetric flask. A 25.0 cm^3 portion was pipetted into a conical flask and excess potassium iodide solution was added. The liberated iodine was titrated with 0.100 mol dm^{-3} sodium thiosulfate solution; starch solution was added just before the end point and the titre was 20.0 cm^3 .

(i) Write a half-equation for the reduction of dichromate(VI) ions to Cr^{3+} .

_____ [1]

(ii) Write a half-equation for the oxidation of iodide ions to iodine.

_____ [1]

(iii) Combine the two half-equations in (b)(i) and (b)(ii) to give the redox equation for the overall reaction between dichromate(VI) ions and iodide ions.

_____ [1]



(iv) Suggest why the solution may not be colourless at the end point of the titration.

_____ [1]

(v) Explain why starch solution is added just before the end point, rather than at the start of each titration.

_____ [1]

(vi) Calculate the percentage purity of the 1.0g sample of sodium dichromate(VI). Give your answer to 1 decimal place.

Answer _____ % [5]

[Turn over

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(c) In aqueous solution, the Cr^{3+} ion is present as the complex ion $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$.

(i) Suggest the name of the complex ion $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$.

_____ [1]

(ii) When aqueous ammonia or sodium hydroxide solution is added to $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$, a precipitate of chromium(III) hydroxide forms. State the colour of the precipitate.

_____ [1]

(iii) The reaction in (c)(ii) is described as deprotonation. Suggest the meaning of this term.

_____ [1]

(iv) On addition of concentrated ammonia to the precipitate formed in (c)(ii), a purple solution forms containing hexaamminechromium(III) ions. Suggest an equation for this reaction.

_____ [2]





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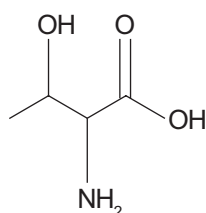
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- 16 Threonine is described as an essential amino acid as it cannot be synthesised in the human body, it must come from the diet. The skeletal formula of threonine is shown below.



threonine

- (a) State the IUPAC name for threonine.

_____ [2]

- (b) Write the molecular formula of threonine.

_____ [1]

- (c) State the number of chiral centres present in a molecule of threonine.

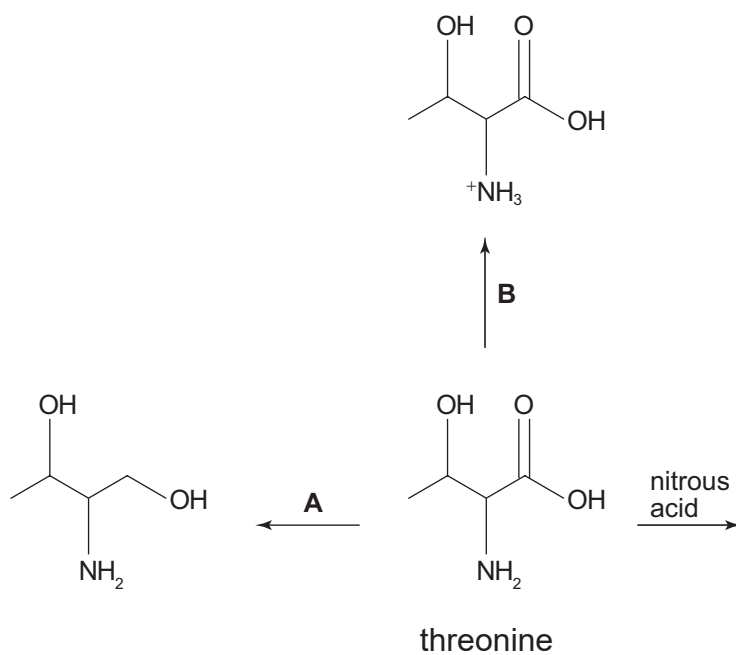
_____ [1]

- (d) Explain why threonine has a very high melting point.

_____ [2]



(e) Some reactions of threonine are shown in the diagram below.



(i) Name suitable reagents for reactions **A** and **B**.

A _____

B _____ [2]

(ii) State the systematic name for nitrous acid.

_____ [1]

(iii) Nitrous acid is formed in situ. Name the reagents which are added to form nitrous acid.

_____ [2]



(iv) Write an equation for the reaction of threonine with nitrous acid. State the IUPAC name of the organic product.

Equation:

IUPAC name of organic product:

[3]



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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 = $3 \times 10^8 \text{ m s}^{-1}$



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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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

gce a/as examinations

chemistry

I II **THE PERIODIC TABLE OF ELEMENTS** III IV V VI VII 0
Group

1 H Hydrogen 1																			4 He Helium 2					
7 Li Lithium 3	9 Be Beryllium 4																		11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12																		27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36							
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	98 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54							
133 Cs Caesium 55	137 Ba Barium 56	139 La* Lanthanum 57	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	210 Po Polonium 84	210 At Astatine 85	222 Rn Radon 86							
223 Fr Francium 87	226 Ra Radium 88	227 Ac† Actinium 89	261 Rf Rutherfordium 104	262 Db Dubnium 105	266 Sg Seaborgium 106	264 Bh Bohrium 107	277 Hs Hassium 108	268 Mt Meitnerium 109	271 Ds Darmstadtium 110	272 Rg Roentgenium 111	285 Cn Copernicium 112													

* 58 – 71 Lanthanum series
† 90 – 103 Actinium series

$\begin{matrix} a \\ \boxed{X} \\ b \end{matrix}$ a = relative atomic mass (approx)
x = atomic symbol
b = atomic number

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	145 Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
232 Th Thorium 90	231 Pa Protactinium 91	238 U Uranium 92	237 Np Neptunium 93	242 Pu Plutonium 94	243 Am Americium 95	247 Cm Curium 96	245 Bk Berkelium 97	251 Cf Californium 98	254 Es Einsteinium 99	253 Fm Fermium 100	256 Md Mendelevium 101	254 No Nobelium 102	257 Lr Lawrencium 103