



Rewarding Learning

ADVANCED
General Certificate of Education
2024

Centre Number

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Candidate Number

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Chemistry

StemUp Model Solution

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.



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 D [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 D [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 D [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 D [1]

[Turn over]



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

Half-cell	$E^\ominus / \text{V}$
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	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

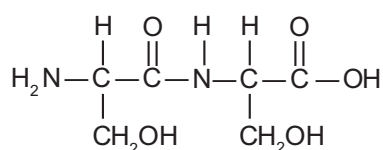
Which one of the following statements is correct?

- 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 C [1]

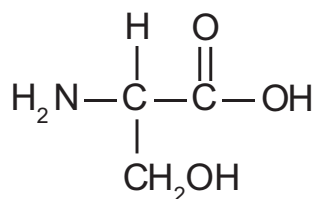


- 6 The dipeptide formed from the amino acid serine is shown below.

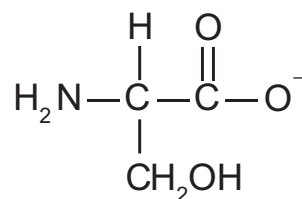


The dipeptide was heated with aqueous hydroxide ions until no further change took place. Which one of the following products was formed?

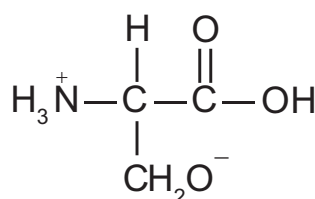
A



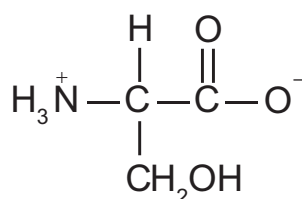
B



C



D



Answer B [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 A [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 D [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 B [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 C [1]





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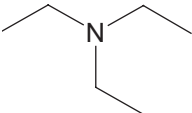
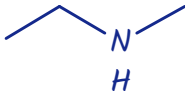
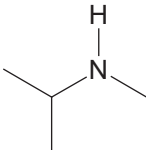


Section B

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	Primary
	$C_6H_{15}N$	Tertiary
	C_3H_9N	Secondary
	$C_4H_{11}N$	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.

Filter off the crude solid amide formed from each isomer

separately.

Recrystallise each solid from hot ethanol, then filter and dry.

Determine the melting point of each purified solid and compare

with data book values to identify the amines.

[4]

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

Secondary amines have two electron-releasing alkyl groups, so the

lone pair of electrons on the nitrogen is more available for

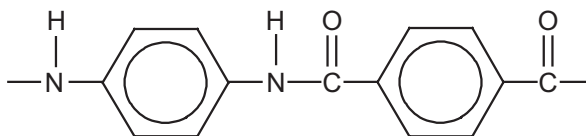
protonation (accepting H^+).

[1]

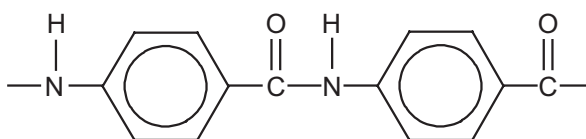
[Turn over]



- (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.

They have the same molecular formula but different structures

(structural formulae).

[1]

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

benzene-1,4-diamine

benzene-1,4-dicarboxylic acid (terephthalic acid)

[2]

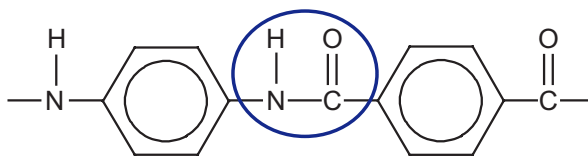
- (iii) Name the single monomer used to form Polymer B.

4-aminobenzoic acid

[1]



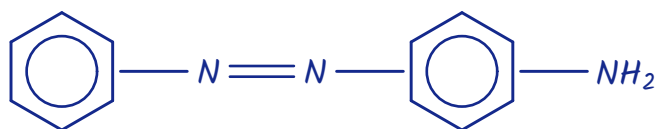
(iv) Circle the amide group in Polymer A, below.



[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.

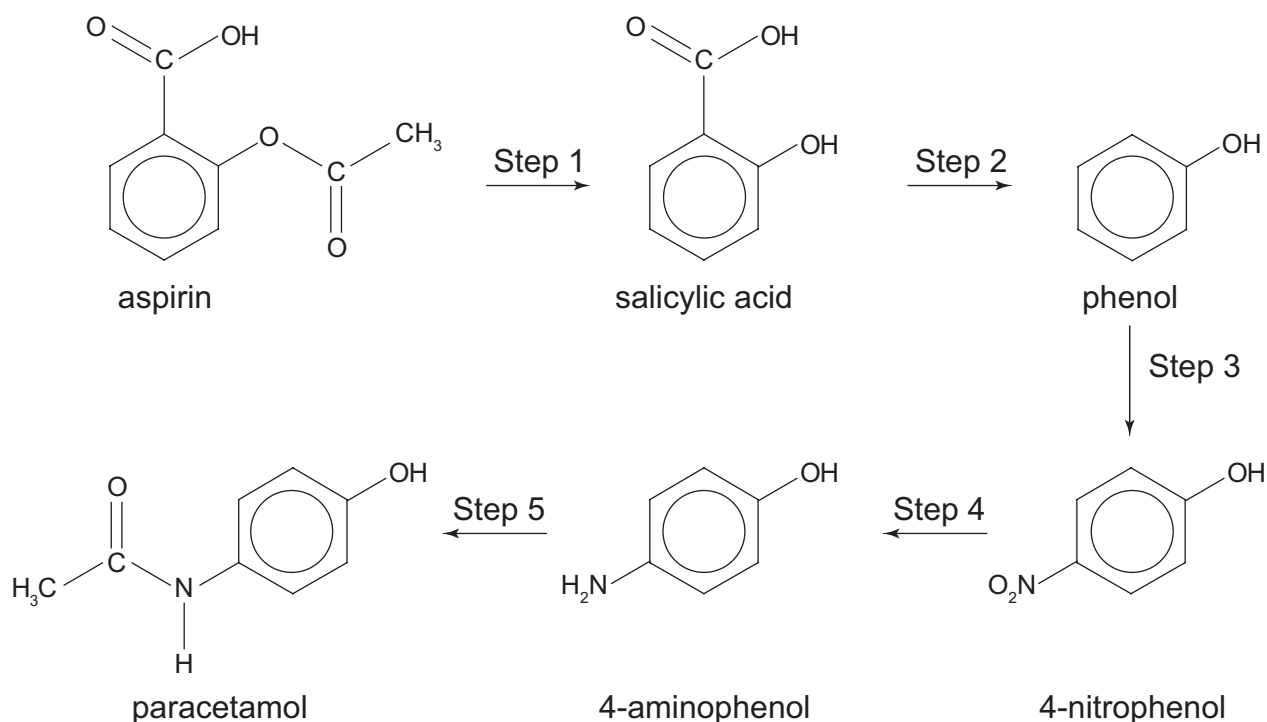
Azo dyes have an extended delocalised system of electrons. This brings the electron energy levels closer together, so the dye absorbs light in the visible region (the colour not absorbed is seen).

[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.

hydrolysis

dilute hydrochloric acid (heat under reflux)

[2]

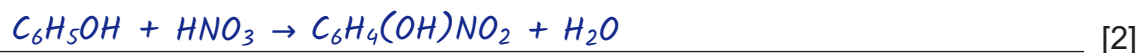
- (b) A gas is formed in Step 2. Suggest the name of the gas.

carbon dioxide

[1]



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



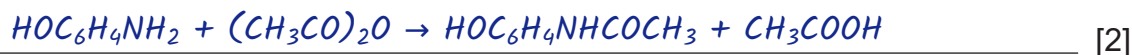
(d) (i) Tin is used in Step 4. Suggest why it is incorrect to describe tin as a catalyst in Step 4.

Tin is oxidised (it is the reducing agent), so it is used up and not regenerated at the end of the reaction. [1]

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

concentrated hydrochloric acid
sodium hydroxide solution [2]

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



[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**.

A peak produced by the ion formed when one electron is removed from a molecule (M^+).

[1]

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

Compound D ($\text{CH}_3\text{COOCH}_2\text{CH}_3$), as it has the highest RMM (88, compared with 72 for A, B and C).

[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.

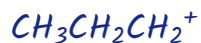
base peak

[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

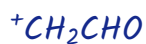


B



[2]

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



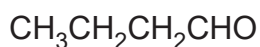
[1]

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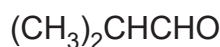


- (c) The nmr spectra of compounds **A** and **B** can be used to distinguish between the two compounds.

Compound **A**



Compound **B**



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

A 4

B 3 [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.

the hydrogen atom of the aldehyde group, -CHO [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.

In A the CHO hydrogen is next to a carbon with two hydrogen atoms (CH₂), so $n + 1 = 3$ gives a triplet.

In B the adjacent carbon has only one hydrogen atom (CH), so $n + 1 = 2$ gives a doublet. [2]





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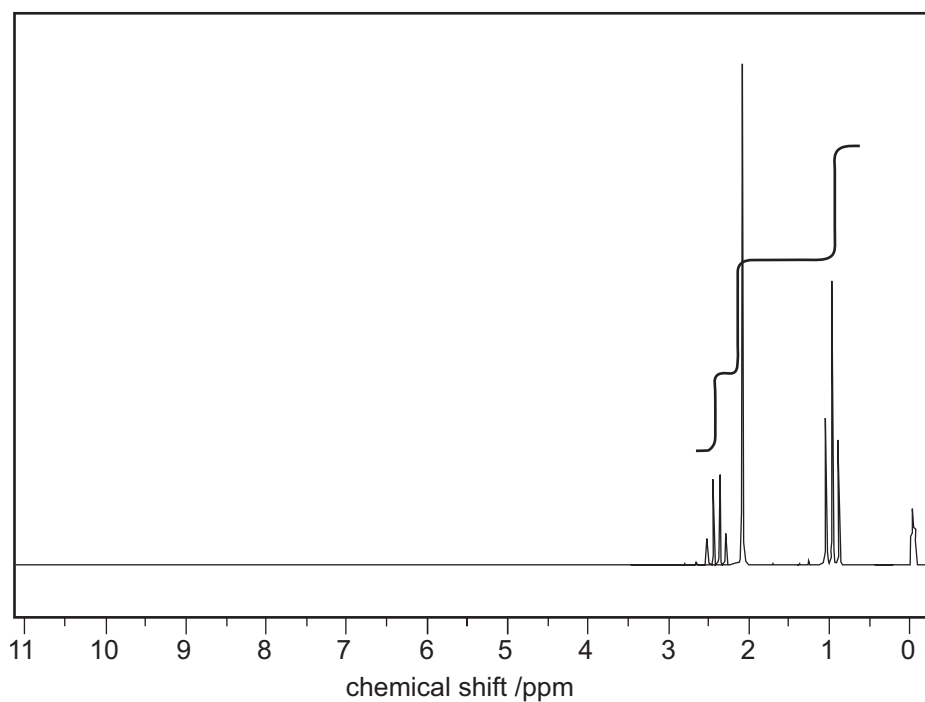
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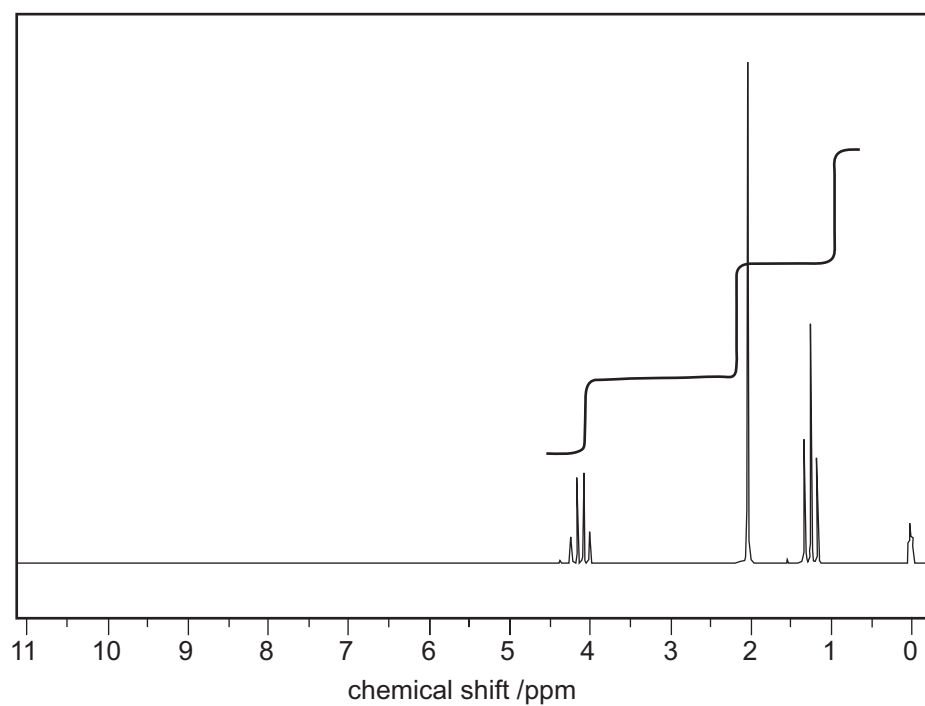


(d) The nmr spectra of compounds **C** and **D** are shown below.

Compound C



Compound D



- (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.

tetramethylsilane (TMS). It is a standard for comparison of chemical shifts.

All its H atoms are chemically equivalent, giving one strong singlet, and are more shielded than H atoms in organic compounds. [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.

Similarities: both spectra contain three sets of peaks (three hydrogen environments).

The integration ratio is 3 : 3 : 2 in both spectra.

Both show the same spin-spin splitting pattern: a singlet, a triplet and a quartet.

In both, the triplet (CH_3 next to CH_2) is at the lowest chemical shift, and both have a singlet at $\delta = 2.0$ ppm from the CH_3 with no neighbouring hydrogens.

Difference: the quartet (CH_2) is at a lower chemical shift in compound C (about 2.5 ppm, next to $\text{C}=\text{O}$).

In compound D the quartet is at a higher chemical shift (about 4.1 ppm) because the CH_2 is bonded to the extra, electronegative oxygen atom of the ester, which deshields it. [6]

[Turn over



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

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

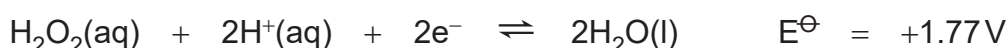
The potential difference (emf) measured when a half-cell is

connected to the standard hydrogen electrode under standard

conditions (298 K, 100 kPa, 1 mol dm⁻³).

[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**.

The potential difference measured between two half-cells when

they are connected.

[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.

emf = +1.77 - (+0.68) = +1.09 V

The cell emf is positive, so the decomposition is feasible.

[2]

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

The reaction has a high activation energy, so it is very slow.

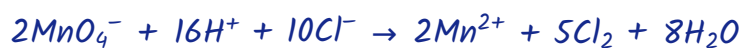
[1]



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

Half-cell	$E^\ominus / \text{V}$
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+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.



$E^\ominus$ for $\text{MnO}_4^-/\text{Mn}^{2+}$ (+1.51 V) is more positive than for Cl_2/Cl^-

(+1.36 V), so manganate(VII) ions oxidise chloride ions to chlorine

(emf = +0.15 V), using up some of the manganate(VII).

[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]

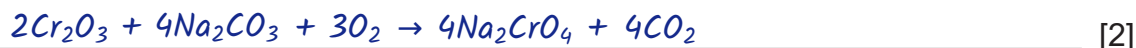
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15 Sodium dichromate(VI), $\text{Na}_2\text{Cr}_2\text{O}_7$, is an orange solid which is produced on a large scale from ores containing chromium(III) oxide. An acidified solution of dichromate(VI) ions can act as an oxidising agent.

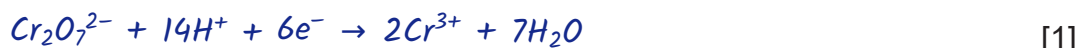
- (a)** Chromium(III) oxide is heated with sodium carbonate and oxygen to produce sodium chromate(VI), Na_2CrO_4 , and carbon dioxide.

Write an equation for this reaction.



- (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 .

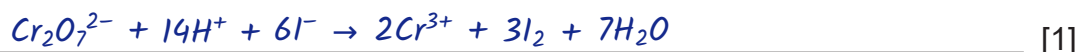
- (i)** Write a half-equation for the reduction of dichromate(VI) ions to Cr^{3+} .



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



- (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.



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

The Cr^{3+} ions formed are green, so the solution is green at the end point.

[1]

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

At high iodine concentration starch forms an insoluble (irreversible) complex with iodine, giving an inaccurate end point.

[1]

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

$$\text{moles } \text{S}_2\text{O}_3^{2-} = 20.0 \times 0.100 \div 1000 = 0.00200 \text{ mol}$$

$$\text{moles } \text{I}_2 = 0.00200 \div 2 = 0.00100 \text{ mol in } 25.0 \text{ cm}^3$$

$$\text{moles } \text{I}_2 \text{ in } 250 \text{ cm}^3 = 0.00100 \times 10 = 0.0100 \text{ mol}$$

$$\text{moles } \text{Cr}_2\text{O}_7^{2-} = 0.0100 \div 3 = 0.00333 \text{ mol}$$

$$M_r \text{ Na}_2\text{Cr}_2\text{O}_7 = 46 + 104 + 112 = 262$$

$$\text{mass Na}_2\text{Cr}_2\text{O}_7 = 0.00333 \times 262 = 0.872 \text{ g}$$

$$\% \text{ purity} = 0.872 \div 1.0 \times 100 = 87.2 \%$$

Answer 87.2 % [5]

[Turn over]



(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 $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$.

hexaaquachromium(III) ion [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.

green-blue (grey-green) [1]

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

Removal of a hydrogen ion (proton) from a water ligand. [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.

$[\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3] + 6\text{NH}_3 \rightarrow$
 $[\text{Cr}(\text{NH}_3)_6]^{3+} + 3\text{H}_2\text{O} + 3\text{OH}^-$ [2]





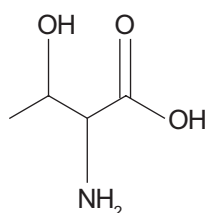
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- 16 Threonine is described as an essential amino acid as it cannot be synthesised in the human body, it must come from the diet. The skeletal formula of threonine is shown below.



threonine

- (a) State the IUPAC name for threonine.

2-amino-3-hydroxybutanoic acid [2]

- (b) Write the molecular formula of threonine.

$C_4H_9NO_3$ [1]

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

2 [1]

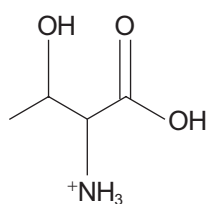
- (d) Explain why threonine has a very high melting point.

Threonine exists as a zwitterion (dipolar ion), $^+H_3N-CH(R)-COO^-$.

There is strong ionic bonding (electrostatic attraction between oppositely charged groups) in the solid, which needs a lot of energy to overcome.

[2]





B

A

nitrous
acid

threonine

- (i) Name suitable reagents for reactions **A** and **B**.
- A** *lithal (LiAlH_4) in dry ether*

A lithal (LiAlH_4) in dry ether

B *dilute hydrochloric acid* [2]

- (ii) State the systematic name for nitrous acid.
- nitric(III) acid*
- [1]

nitric(III) acid

- (iii) Nitrous acid is formed in situ. Name the reagents which are added to form nitrous acid.
- sodium nitrite (sodium nitrate(III))*

sodium nitrite (sodium nitrate(III))

hydrochloric acid [2]

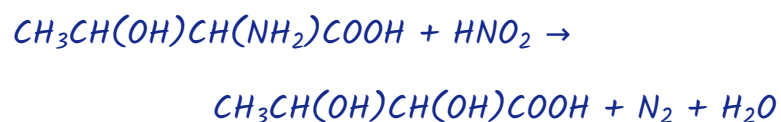
hydrochloric acid

14028



- (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:

2,3-dihydroxybutanoic acid

[3]



- (f) Threonine along with other amino acids is used in the human body to make proteins.

Describe the structure of proteins in terms of primary, secondary and tertiary structures. Include in your answer the names of the type of links/bonds that hold the primary and secondary structures together and one example of a bond that holds the tertiary structure together.

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

The primary structure of a protein is the sequence of amino acids in the polypeptide chain.

The amino acids in the primary structure are held together by amide (peptide) links, $-\text{CONH}-$, formed in condensation reactions.

The secondary structure is formed by the coiling or twisting of the amino acid chain into an α -helix, or folding into a β -pleated sheet.

The secondary structure is held together by intramolecular hydrogen bonding between the $\text{C}=\text{O}$ of one peptide link and the $\text{N}-\text{H}$ of another.

The tertiary structure is the final folding (bending) of the whole chain into a specific three-dimensional shape.

The tertiary structure is held together by interactions between the R groups, for example disulfide bridges ($\text{S}-\text{S}$), hydrogen bonds, ionic interactions and van der Waals forces.

[6]



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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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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

gce a/as examinations chemistry

THE PERIODIC TABLE OF ELEMENTS																	
Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen																	4 He Helium
7 Li Lithium	9 Be Beryllium											11 B Boron	12 C Carbon	14 N Nitrogen	16 O Oxygen	19 F Fluorine	20 Ne Neon
23 Na Sodium	24 Mg Magnesium											27 Al Aluminium	28 Si Silicon	31 P Phosphorus	32 S Sulfur	35.5 Cl Chlorine	40 Ar Argon
39 K Potassium	40 Ca Calcium	45 Sc Scandium	48 Ti Titanium	51 V Vanadium	52 Cr Chromium	55 Mn Manganese	56 Fe Iron	59 Co Cobalt	59 Ni Nickel	64 Cu Copper	65 Zn Zinc	70 Ga Gallium	73 Ge Germanium	75 As Arsenic	79 Se Selenium	80 Br Bromine	84 Kr Krypton
85 Rb Rubidium	88 Sr Strontium	89 Y Yttrium	91 Zr Zirconium	93 Nb Niobium	96 Mo Molybdenum	98 Tc Technetium	101 Ru Ruthenium	103 Rh Rhodium	106 Pd Palladium	108 Ag Silver	112 Cd Cadmium	115 In Indium	119 Sn Tin	122 Sb Antimony	128 Te Tellurium	127 I Iodine	131 Xe Xenon
133 Cs Caesium	137 Ba Barium	139 La [*] Lanthanum	178 Hf Hafnium	181 Ta Tantalum	184 W Tungsten	186 Re Rhenium	190 Os Osmium	192 Ir Iridium	195 Pt Platinum	197 Au Gold	201 Hg Mercury	204 Tl Thallium	207 Pb Lead	209 Bi Bismuth	210 Po Polonium	210 At Astatine	222 Rn Radon
223 Fr Francium	226 Ra Radium	227 Ac [†] Actinium	261 Rf Rutherfordium	262 Db Dubnium	266 Sg Seaborgium	264 Bh Bohrium	277 Hs Hassium	268 Mt Meitnerium	271 Ds Darmstadtium	272 Rg Roentgenium	285 Cn Copernicium						
			140 Ce Cerium	141 Pr Praseodymium	144 Nd Neodymium	145 Pm Promethium	150 Sm Samarium	152 Eu Europium	157 Gd Gadolinium	159 Tb Terbium	162 Dy Dysprosium	165 Ho Holmium	167 Er Erbium	169 Tm Thulium	173 Yb Ytterbium	175 Lu Lutetium	
			232 Th Thorium	231 Pa Protactinium	238 U Uranium	237 Np Neptunium	242 Pu Plutonium	243 Am Americium	247 Cm Curium	245 Bk Berkelium	251 Cf Californium	254 Es Einsteinium	253 Fm Fermium	256 Md Mendelevium	254 No Nobelium	257 Lr Lawrencium	
			90	91	92	93	94	95	96	97	98	99	100	101	102	103	
			^aX_b a = relative atomic mass (approx) x = atomic symbol b = atomic number														