



Rewarding Learning

ADVANCED
General Certificate of Education
2025

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

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.

14556



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]

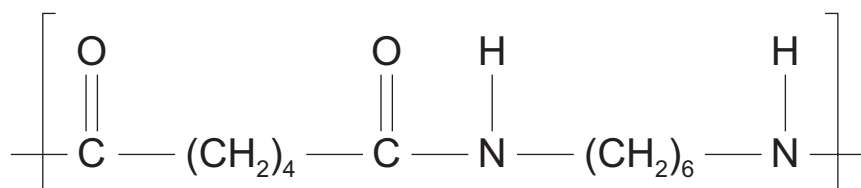
- 2 Which one of the following describes the peaks in the nmr spectrum of ethyl ethanoate?

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]



3 The repeating unit of a polymer is shown below.

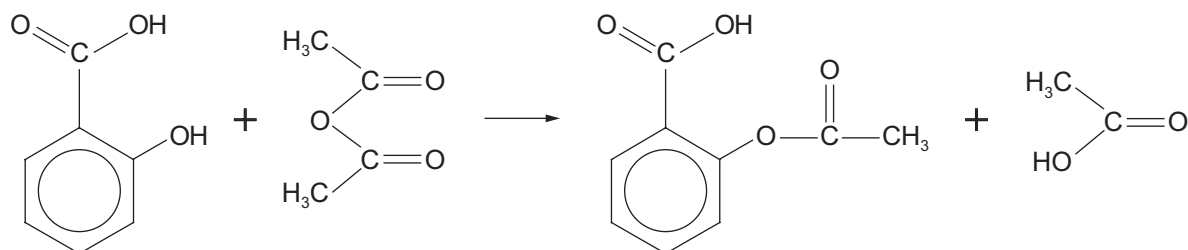


Which one of the following pairs of monomers can be used to produce the polymer which contains this repeating unit?

- | | | |
|---|------------------|-------------------|
| A | butanedioic acid | 1,4-diaminobutane |
| B | butanedioic acid | 1,6-diaminohexane |
| C | hexanedioic acid | 1,4-diaminobutane |
| D | hexanedioic acid | 1,6-diaminohexane |

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

4 What mass of 2-hydroxybenzoic acid would be required to produce 8.0 g of aspirin if the percentage yield is 50%? The ethanoic anhydride is in excess.



- A 4.0 g
- B 6.2 g
- C 12.3 g
- D 16.0 g

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

[Turn over]



- 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 $\text{C}_3\text{H}_7\text{NO}$	$\text{C}_3\text{H}_5\text{N}$
B $\text{C}_3\text{H}_7\text{NO}$	$\text{C}_3\text{H}_4\text{O}$
C $\text{C}_4\text{H}_9\text{NO}$	$\text{C}_4\text{H}_7\text{N}$
D $\text{C}_4\text{H}_{11}\text{N}$	C_4H_8

Answer:

A

B

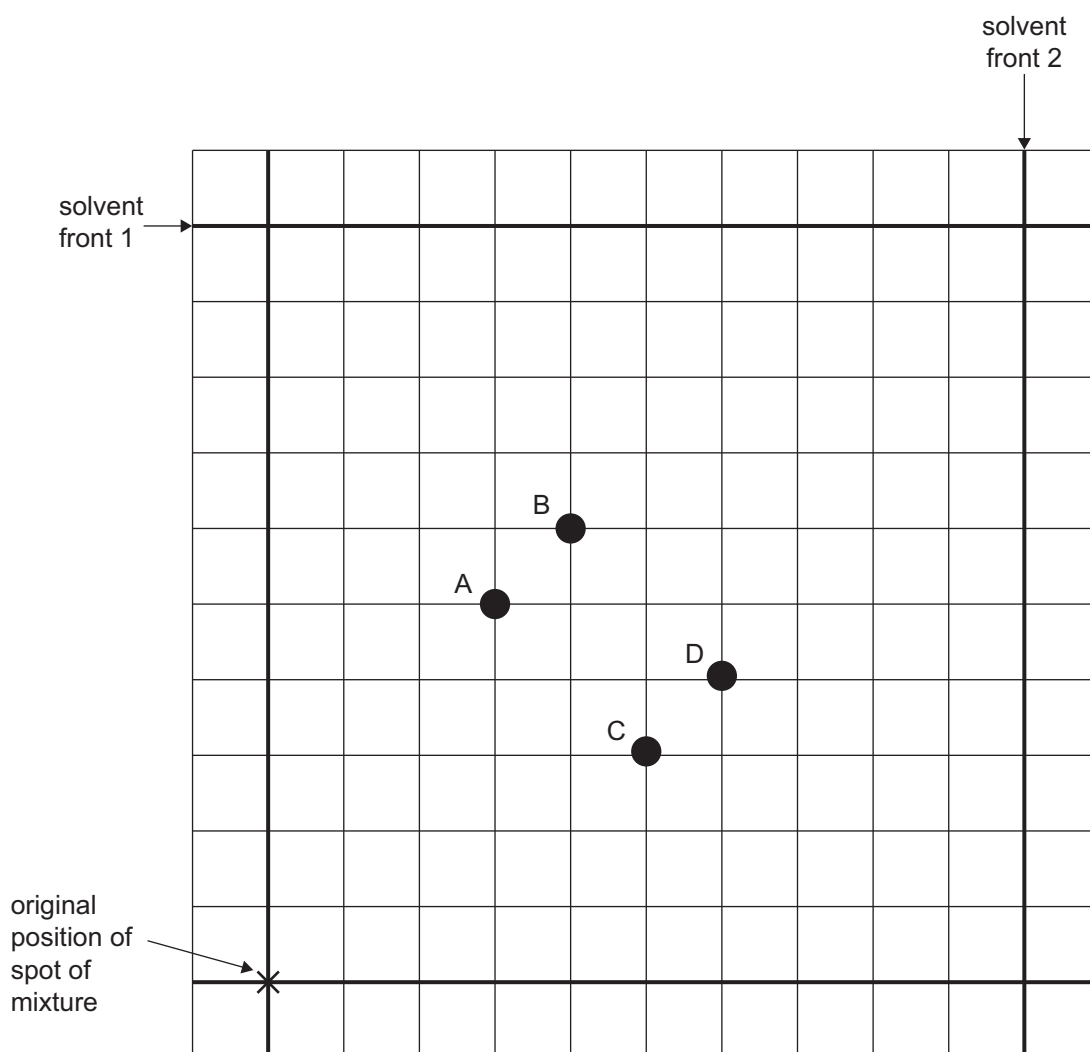
C

D

[1]



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



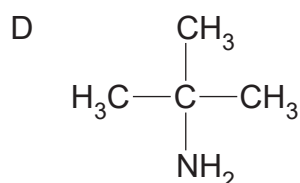
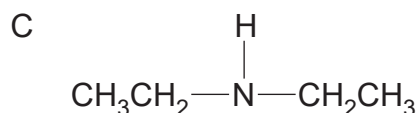
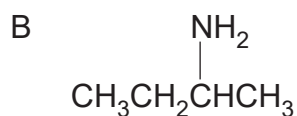
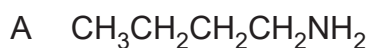
Which one of the spots (A, B, C or D) has an R_f value of 0.6 in solvent 1 and 0.4 in solvent 2?

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.

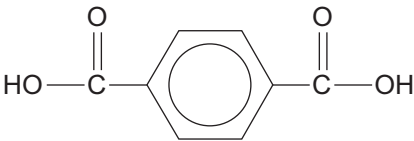
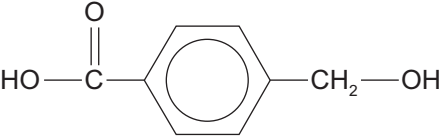
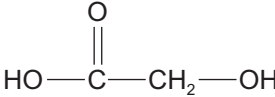
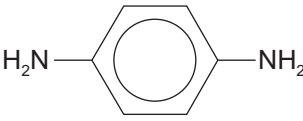
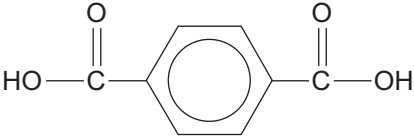
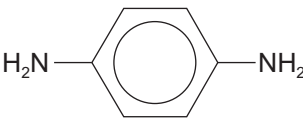
Which one of the following gives a suitable indicator and the colour change at the end point of the titration?

- | | | |
|---|-----------------|--------------------|
| 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]

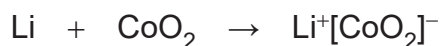


- 9 Which one of the following pairs of monomers could **not** be used to produce a condensation polymer?

A		$\text{HOCH}_2\text{CH}_2\text{OH}$
B		
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.

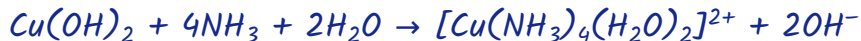
(i) A few drops of aqueous ammonia were added to the first portion of copper(II) sulfate solution and a precipitate formed. Give the formula and colour of the precipitate.

Formula: $\text{Cu}(\text{OH})_2$

Colour: pale blue [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.

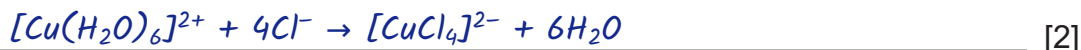
Ionic equation:



Final colour of solution: deep blue [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.



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

From blue to yellow-green [1]



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

Complex ion	Co-ordination number	Shape
$[\text{Co}(\text{H}_2\text{O})_6]^{2+}$	6	octahedral
$[\text{CoCl}_4]^{2-}$	4	tetrahedral

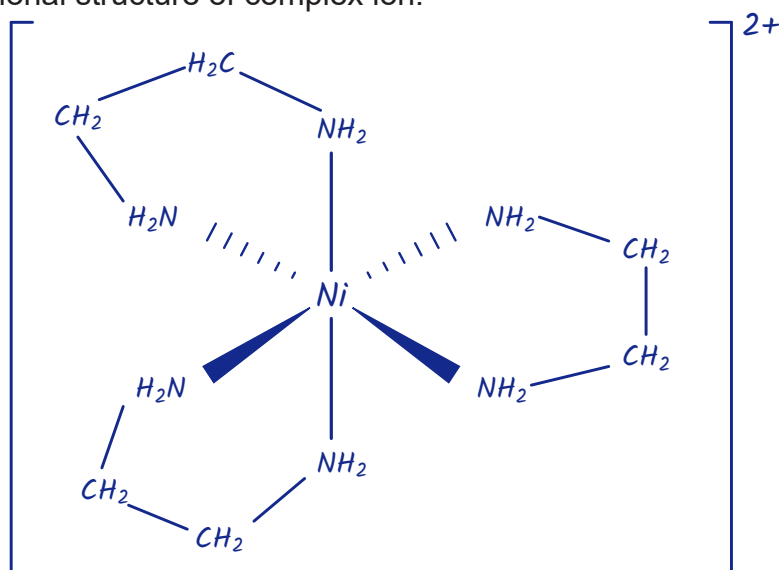
[2]

- (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: green

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] $3d^2$
Cr	[Ar] $3d^5 4s^1$	Cr^{3+}	[Ar] $3d^3$
Cu	[Ar] $3d^{10} 4s^1$	Cu^{2+}	[Ar] $3d^9$
Zn	[Ar] $3d^{10} 4s^2$	Zn^{2+}	[Ar] $3d^{10}$

[4]

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

An element which forms at least one stable ion with a partially filled d-subshell.

[1]



12 Redox titrations can be used to determine the concentration of reducing agents.

- (a) Describe how you would carry out a titration to determine the concentration of a solution containing iron(II) ions. Include the colour change which would be observed and any steps you would take to ensure accuracy.

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

Using a pipette and pipette filler, transfer 25.0 cm³ of the iron(II)

solution into a conical flask.

Add an excess of dilute sulfuric acid to the flask.

Rinse a burette with the standard potassium manganate(VII) solution

and then fill it, recording the initial reading (read from the top of the meniscus as the solution is so dark).

Add the potassium manganate(VII) solution from the burette to the

conical flask while swirling the flask, with the flask on a white tile.

Near the end point add the manganate(VII) solution dropwise.

The end point is when the solution changes from colourless (very pale green) to the first permanent pale pink colour.

Record the final burette reading and repeat the titration until

concordant titres (within 0.10 cm³) are obtained, then calculate the

mean titre.

[6]

[Turn over]



- (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**.

A solution of accurately known concentration.

[1]

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

$$M_r \text{ of } \text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O} = 2 + 24 + 64 + 36 = 126$$

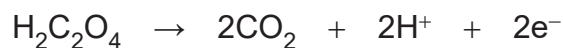
$$\text{moles} = 3.30 \div 126 = 0.02619 \text{ mol in } 250 \text{ cm}^3$$

$$\text{concentration} = 0.02619 \times 4 = 0.105 \text{ mol dm}^{-3}$$

Answer 0.105 mol dm^{-3} [2]



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

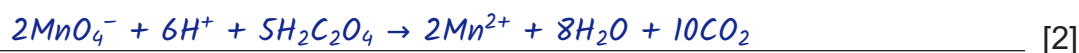


Write a half-equation for the reduction of manganate(VII) ions. Combine the half-equations to give an overall redox equation.

Half-equation:



Overall redox equation:



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

$$\text{moles H}_2\text{C}_2\text{O}_4 = 20.0 \times 0.105 \div 1000 = 2.10 \times 10^{-3} \text{ mol}$$

$$\text{moles MnO}_4^- = 2.10 \times 10^{-3} \times 2 \div 5 = 8.40 \times 10^{-4} \text{ mol}$$

$$\begin{aligned} \text{concentration} &= 8.40 \times 10^{-4} \times 1000 \div 16.0 \\ &= 0.0525 \text{ mol dm}^{-3} \end{aligned}$$

Answer 0.0525 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.

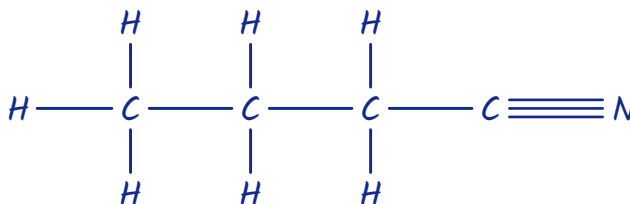


- (i) Name a reagent required for Step 1 and classify the type of reaction which occurs.

Reagent: potassium cyanide (KCN), in ethanol

Type of reaction: nucleophilic substitution [2]

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



IUPAC name: butanenitrile [2]

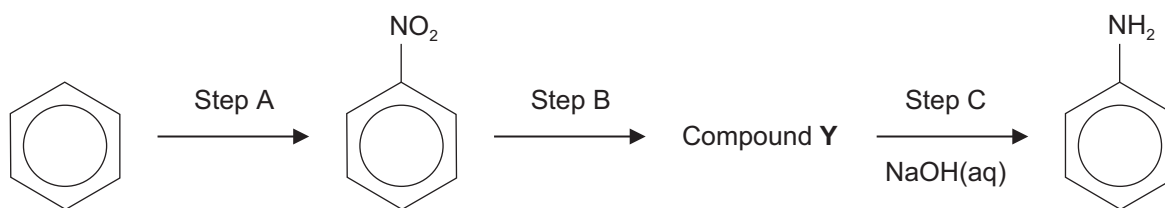
- (iii) Identify the reagent required for Step 2 and classify the type of reaction which occurs.

Reagent: LiAlH_4 (lithal) in dry ether

Type of reaction: reduction [2]



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



(i) Name the organic product of Step A.

nitrobenzene

[1]

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

1. tin

2. concentrated hydrochloric acid

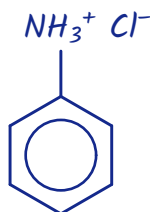
[2]

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

reduction

[1]

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



Name: phenylammonium chloride

[2]

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

To liberate the free amine (phenylamine) from its salt by removing the H^+ (neutralising the acid).

[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?

sodium nitrate(III) [1]

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

$\text{NaNO}_2 + \text{HCl} \rightarrow \text{HNO}_2 + \text{NaCl}$ [1]

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

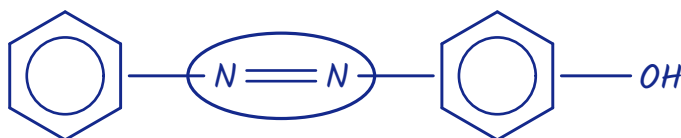
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2 + \text{HNO}_2 \rightarrow$
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{N}_2 + \text{H}_2\text{O}$ [1]

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

benzenediazonium chloride [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.

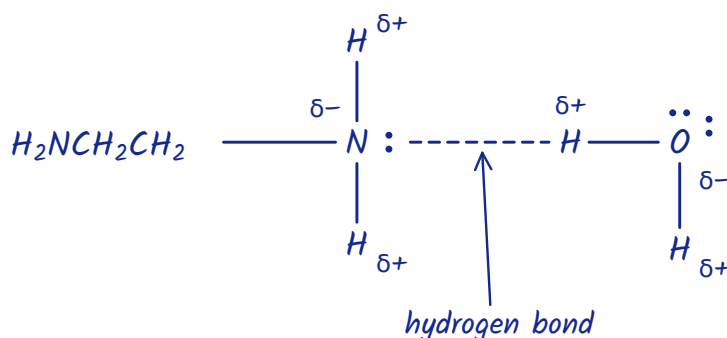


Name of link: azo link ($-N=N-$) [3]



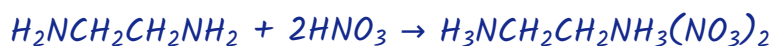
(d) 1,2-diaminoethane is soluble in water, acts as a Brønsted–Lowry base and reacts with an excess of ethanoyl chloride.

(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]

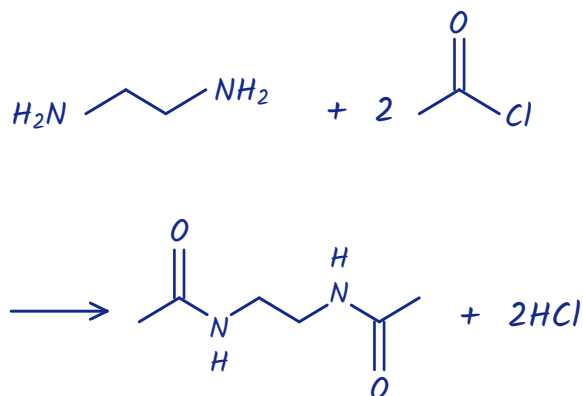
(ii) Write an equation for the reaction of 1,2-diaminoethane with an excess of nitric acid.



[1]



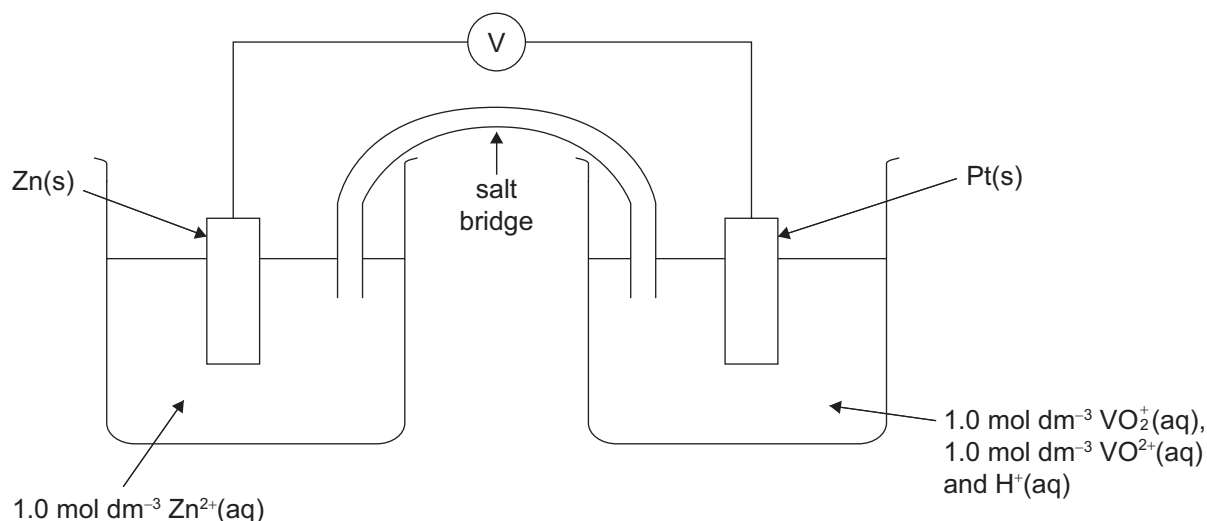
(iii) Using skeletal formulae, write an equation for the reaction of 1,2-diaminoethane with an excess of ethanoyl chloride.



[2]



- 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 +1.76 V.



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**.

The potential difference (EMF) measured when a half-cell is connected to a standard hydrogen electrode under standard conditions.

[1]

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

$\text{Zn}(\text{s}) \mid \text{Zn}^{2+}(\text{aq}) \parallel \text{VO}_2^+(\text{aq}), \text{H}^+(\text{aq}), \text{VO}^{2+}(\text{aq}) \mid \text{Pt}(\text{s})$

[2]



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

$$E_{\text{cell}} = E_{\text{right}} - E_{\text{left}}$$

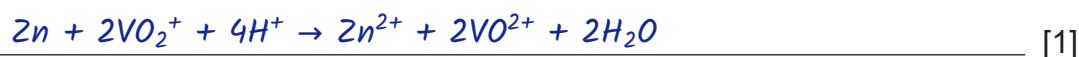
$$+1.76 = E_{\text{right}} - (-0.76)$$

$$E_{\text{right}} = +1.00 \text{ V}$$

Answer +1.00 V [1]

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

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



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



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

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

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

[Turn over]



- (c) The standard hydrogen electrode is used to measure standard electrode potentials.

Write the half-equation, including state symbols, for the standard hydrogen electrode, state its $E^\ominus$ value and describe how it is set up.

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

Half-equation: $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$

Its standard electrode potential is defined as $E^\ominus = 0.00 \text{ V}$.

Set-up: hydrogen gas at a pressure of 100 kPa (1 atm) is bubbled

into a solution containing $1.00 \text{ mol dm}^{-3} \text{H}^+(\text{aq})$ ions, for example

1.00 mol dm^{-3} hydrochloric acid.

The gas passes over an inert platinum electrode (coated with

platinum black), which provides a surface for the equilibrium to be

set up and conducts the electrons.

The electrode is kept at a temperature of 298 K (25 °C).

It is connected to the other half-cell by a salt bridge and a high

resistance voltmeter.

[6]



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.

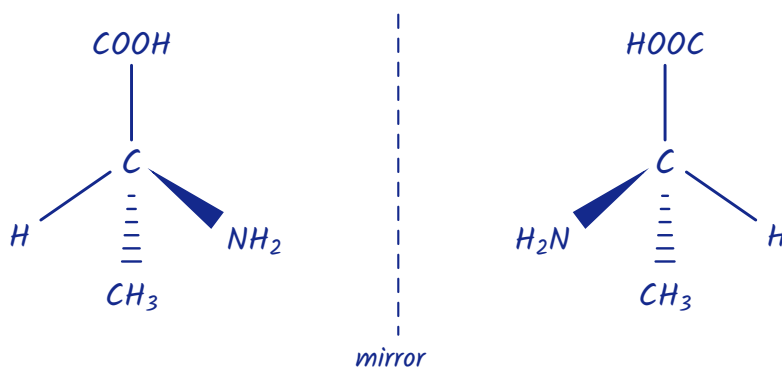
(a) (i) State the IUPAC name of alanine.

2-aminopropanoic acid [1]

(ii) Explain why glycine is optically inactive.

Glycine does not contain an asymmetric (chiral) carbon atom: its central carbon is bonded to two H atoms. [1]

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



[2]

[Turn over]



- (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.

Glycine exists as zwitterions (dipolar ions), $^+\text{H}_3\text{NCH}_2\text{COO}^-$.

In the solid these are held together by strong ionic bonding

(electrostatic attraction between opposite charges).

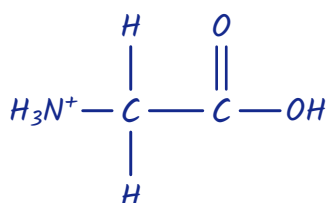
Ionic bonding is much stronger than the hydrogen bonds between

propanoic acid molecules, so more energy is needed to break it.

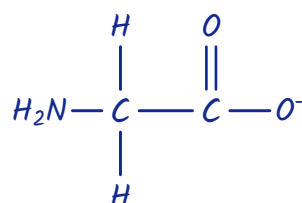
[3]

- (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.

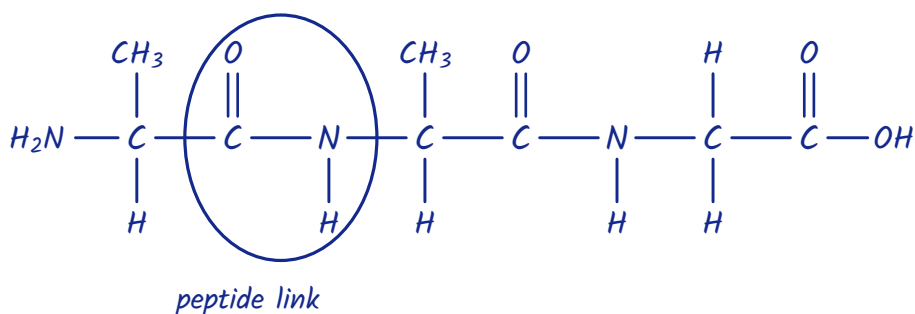
(i) What term is used for molecules which have the same molecular formula but have different structural formulae?

structural isomers [1]

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

condensation [1]

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



[3]

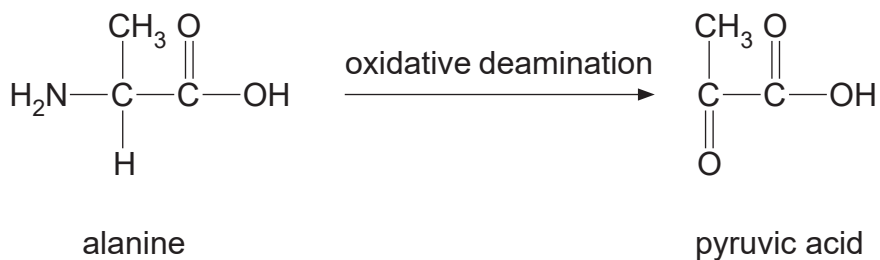
(iv) Classify the type of reaction which would convert the tripeptide back into amino acids.

hydrolysis [1]

[Turn over]



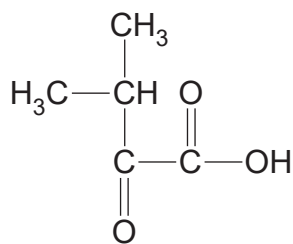
- (e) The human body converts excess amino acids into more useful molecules by a process of oxidative deamination using oxygen. Ammonia is the waste product. Oxidative deamination of alanine produces pyruvic acid.



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



- (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	116
nmr spectroscopy data	
number of environments of chemically equivalent hydrogen atoms	3
peak integration ratio (from highest chemical shift to lowest)	1 : 1 : 6 (COOH : CH : 2 × CH ₃)

[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: the six equivalent H atoms of the two CH₃ groups.

They are split into a doublet by the one H atom on the adjacent

CH ($n + 1 = 2$).

Singlet: the H atom of the COOH group.

It is not split as there are no H atoms bonded to the adjacent

carbon atom.

[4]

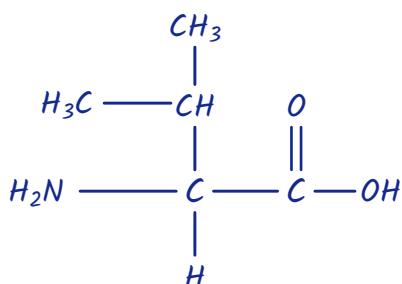
- (iv) Peaks occur at m/z values of 43 and 45 in the mass spectrum of compound **Z**. Identify the fragment ions which cause these peaks.

43 (CH₃)₂CH⁺

45 COOH⁺

[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-amino-3-methylbutanoic acid

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

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



THE PERIODIC TABLE OF ELEMENTS																		
I	II	Group										III	IV	V	VI	VII	0	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
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



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