

Please check the examination details below before entering your candidate information

Candidate surname					Other names						
Centre Number					Candidate Number						
Pearson Edexcel International Advanced Level Monday 03 June 2024 Morning (Time: 1 hour 45 minutes) <table border="1"> <tr> <td>Paper reference</td> <td>WCH15/01</td> </tr> </table>										Paper reference	WCH15/01
Paper reference	WCH15/01										
Chemistry International Advanced Level UNIT 5: Transition Metals and Organic Nitrogen Chemistry											
You must have: Scientific calculator, Data Booklet, ruler								Total Marks			

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
– *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

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SECTION A

Answer ALL questions. Write your answers in the spaces provided.

You should aim to spend no more than 20 minutes on this section.

Some questions must be answered with a cross in a box ☐. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.

1 What colour is vanadium(III) in aqueous solution?

- ☐ A blue
- ☐ B green
- ☐ C purple
- ☐ D yellow

(Total for Question 1 = 1 mark)

2 An oxide of vanadium is the catalyst in one step of the contact process for the manufacture of sulfuric acid.

Which reaction involves the vanadium oxide catalyst and how does the oxidation number of vanadium change during the process?

	Reaction	Oxidation number changes for vanadium
☐ A	$S + O_2 \rightarrow SO_2$	$+5 \rightarrow +4 \rightarrow +5$
☐ B	$SO_2 \rightarrow SO_3$	$+4 \rightarrow +5 \rightarrow +4$
☐ C	$SO_2 \rightarrow SO_3$	$+5 \rightarrow +4 \rightarrow +5$
☐ D	$SO_3 + H_2O \rightarrow H_2SO_4$	$+4 \rightarrow +5 \rightarrow +4$

(Total for Question 2 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.



3 An equation for the reaction of FeSO_4 with KMnO_4 is shown.



(a) Which shows the changes in the oxidation states for iron and manganese?

(1)

	Iron	Manganese
☒ A	II $\rightarrow$ III	VII $\rightarrow$ II
☐ B	II $\rightarrow$ III	VII $\rightarrow$ IV
☐ C	III $\rightarrow$ II	II $\rightarrow$ VII
☐ D	III $\rightarrow$ II	III $\rightarrow$ IV

(b) A 25.00 cm^3 sample of FeSO_4 dissolved in acid required 22.50 cm^3 of $0.100 \text{ mol dm}^{-3} \text{ KMnO}_4$ for complete reaction.

What is the concentration of the FeSO_4 solution?

(1)

- ☐ A $0.011 \text{ mol dm}^{-3}$
- ☐ B $0.100 \text{ mol dm}^{-3}$
- ☐ C $0.450 \text{ mol dm}^{-3}$
- ☐ D $0.900 \text{ mol dm}^{-3}$

(Total for Question 3 = 2 marks)

4 The emf, E_{cell} , of the cell made up of the copper and magnesium half-cells is measured under standard conditions.

The voltmeter used has a measurement uncertainty of 0.50%.

What is the **highest** emf that could be measured in this experiment?

Use your Data Booklet.

- ☒ A 2.70V
- ☐ B 2.72V
- ☐ C 2.74V
- ☐ D 2.85V

(Total for Question 4 = 1 mark)



- 5 Which is the diagram for the cell made up of the nickel and zinc half-cells that gives a positive value for $E_{\text{cell}}^{\ominus}$?

Use your Data Booklet.

- ☐ A $\text{Zn(s)} \mid \text{Zn}^{2+}(\text{aq}) \parallel \text{Ni}^{2+}(\text{aq}) \mid \text{Ni(s)}$
- ☐ B $\text{Zn}^{2+}(\text{aq}) \mid \text{Zn(s)} \parallel \text{Ni(s)} \mid \text{Ni}^{2+}(\text{aq})$
- ☐ C $\text{Ni(s)} \mid \text{Ni}^{2+}(\text{aq}) \parallel \text{Zn}^{2+}(\text{aq}) \mid \text{Zn(s)}$
- ☐ D $\text{Ni}^{2+}(\text{aq}) \mid \text{Ni(s)} \parallel \text{Zn(s)} \mid \text{Zn}^{2+}(\text{aq})$

(Total for Question 5 = 1 mark)

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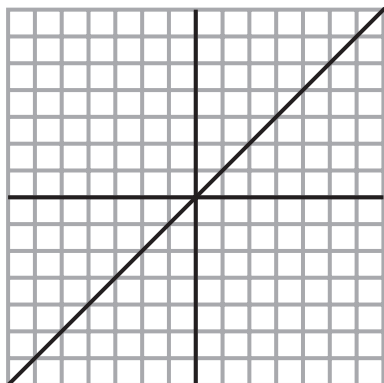
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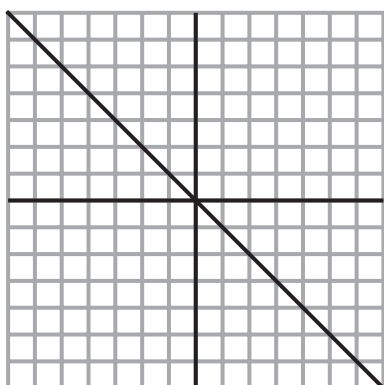
- 6 Which graph shows the relationship between $E_{\text{cell}}^{\ominus}$ plotted on the x-axis and ΔS_{total} on the y-axis for any electrochemical system?



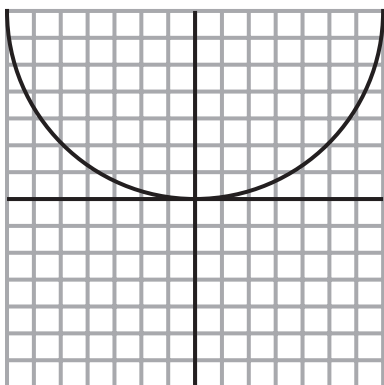
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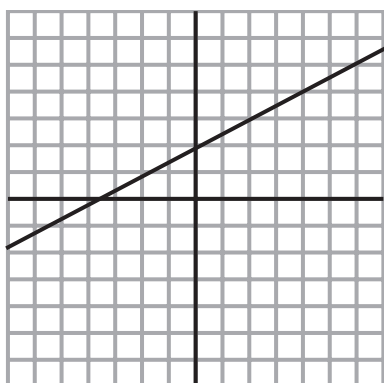
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C



D



(Total for Question 6 = 1 mark)

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7 Which type of data is **not** used as evidence for the structure or stability of the benzene ring?

- ☐ A infrared spectroscopy
- ☐ B mass spectrometry
- ☐ C thermochemical
- ☐ D X-ray diffraction

(Total for Question 7 = 1 mark)

8 The formation of nitrobenzene requires benzene and concentrated nitric and sulfuric acids.

Which is an equation for the reaction to form the electrophile?

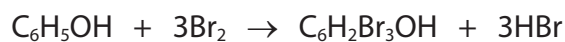
- ☐ A $\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{NO}_2^+ + \text{SO}_4^{2-} + \text{H}_3\text{O}^+$
- ☐ B $\text{HNO}_3 + 2\text{H}_2\text{SO}_4 \rightarrow \text{NO}_2^+ + 2\text{HSO}_4^- + \text{H}_3\text{O}^+$
- ☐ C $\text{HNO}_2 + 2\text{H}_2\text{SO}_4 + \text{H}_2\text{O} \rightarrow \text{NO}_3^+ + 2\text{HSO}_4^- + 5\text{H}^+$
- ☐ D $\text{HNO}_3 + 3\text{H}_2\text{SO}_4 + \text{OH}^- \rightarrow \text{NO}_2 + 3\text{HSO}_4^- + \text{H}_3\text{O}^+ + \text{H}_2\text{O}$

(Total for Question 8 = 1 mark)

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9 Phenol reacts with bromine to form 2,4,6-tribromophenol.



[M_r values: $\text{C}_6\text{H}_5\text{OH} = 94.0$ $\text{Br}_2 = 159.8$ $\text{C}_6\text{H}_2\text{Br}_3\text{OH} = 330.7$ $\text{HBr} = 80.9$]

(a) What is the percentage atom economy (by mass) for the formation of 2,4,6-tribromophenol?

(1)

- ☐ A 42.3%
- ☐ B 57.7%
- ☐ C 69.0%
- ☐ D 100%

(b) When 5.00 g of phenol was reacted and purified, the percentage yield of 2,4,6-tribromophenol was 76.8%.

What mass of purified 2,4,6-tribromophenol was formed?

(1)

- ☐ A 3.84 g
- ☐ B 13.5 g
- ☐ C 17.6 g
- ☐ D 22.9 g

(Total for Question 9 = 2 marks)

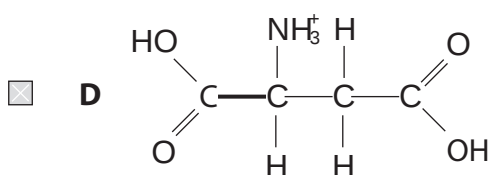
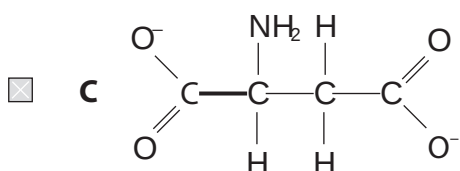
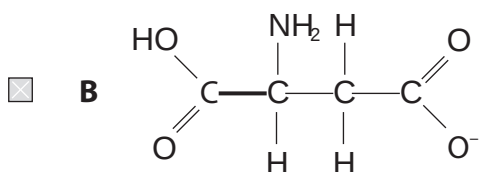
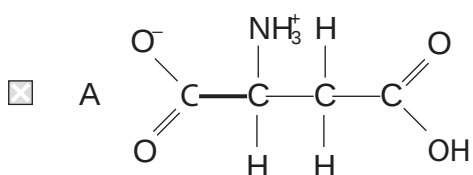
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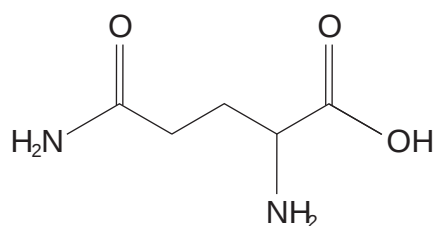
10 Aspartic acid is a naturally-occurring amino acid.

(a) Which form of aspartic acid is formed at pH 12?

(1)



(b) Glutamine is shown.



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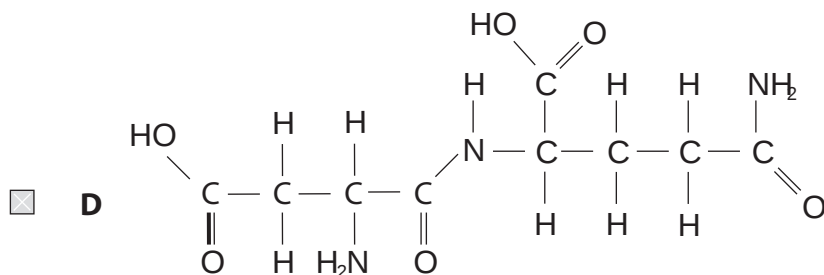
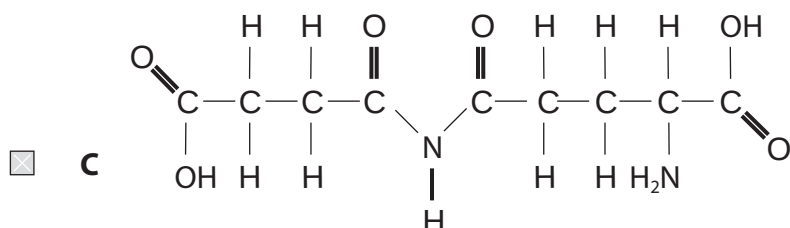
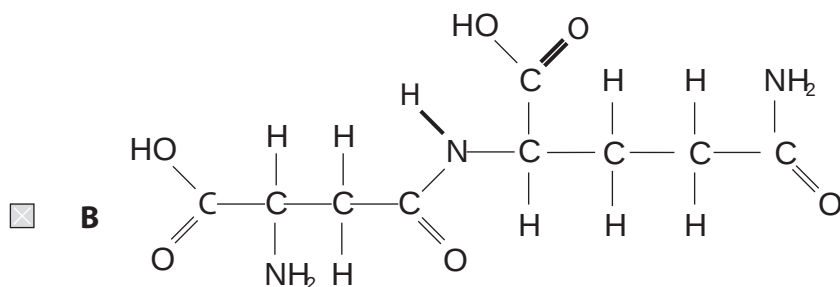
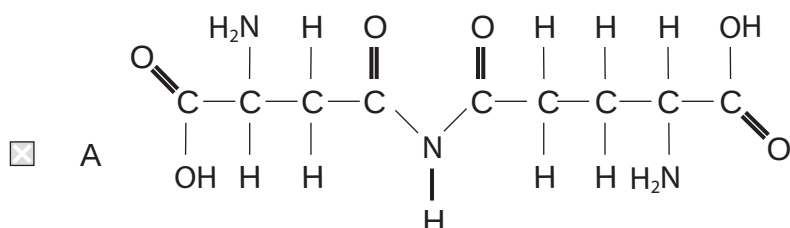
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- (i) Which is a correct structure when aspartic acid forms a dipeptide with glutamine?

(1)



- (ii) What is the maximum number of chiral centres in the dipeptides in (b)(i)?

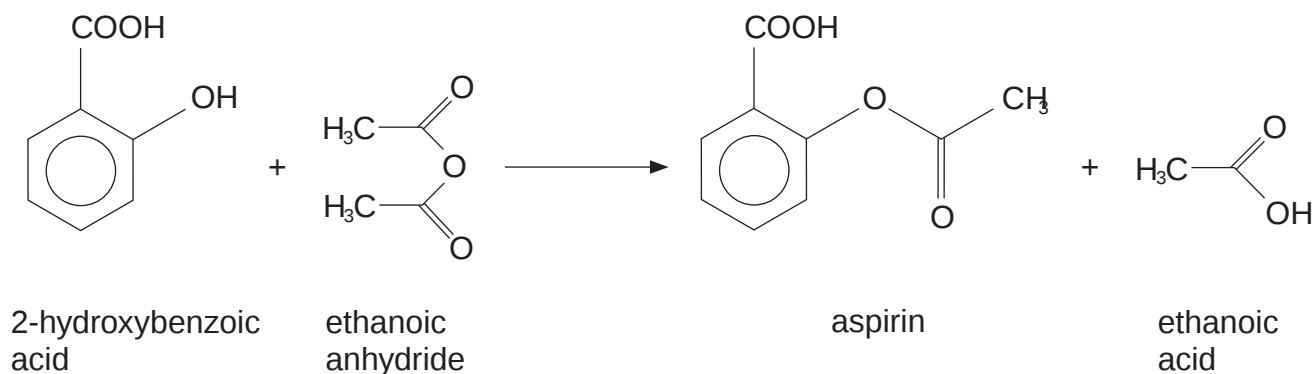
(1)

- ☐ **A** 0
☒ **B** 1
☒ **C** 2
☒ **D** 3

(Total for Question 10 = 3 marks)

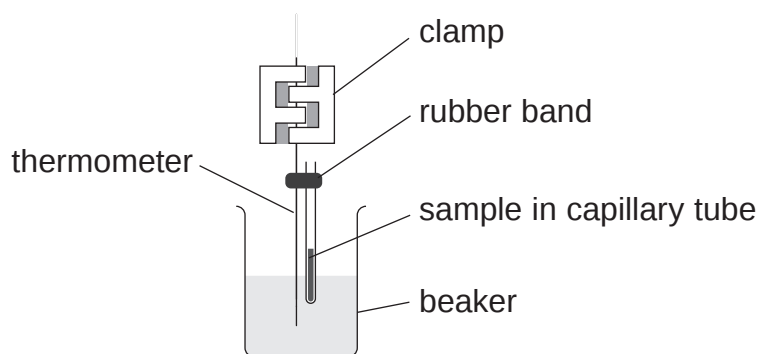


11 A student prepared a sample of aspirin. The equation for the reaction is shown.



The aspirin was recrystallised using an ethanol–water mixture as the solvent.

The student determined its melting temperature using the apparatus shown.



The student's sample melted over a range of 8 degrees starting at 125°C

The published melting temperature of pure aspirin is 135°C .

(a) Which is a suitable liquid to go in the beaker?

(1)

- ☒ A deionised water
- ☐ B ethanol
- ☐ C hexane
- ☐ D mineral oil

(b) Which is likely to be the main impurity in the sample of aspirin?

(1)

- ☐ A ethanoic acid
- ☐ B ethanoic anhydride
- ☐ C ethanol
- ☐ D 2-hydroxybenzoic acid

(Total for Question 11 = 2 marks)



12 Grignard reagents are very useful for increasing the length of the carbon chain of organic compounds.

(a) Which metal is involved in the formation of a Grignard reagent?

(1)

- ☐ A chromium
- ☐ B copper
- ☐ C magnesium
- ☐ D manganese

(b) What best describes the role of a Grignard reagent in increasing the length of a carbon chain?

(1)

- ☐ A reducing agent
- ☐ B oxidising agent
- ☐ C nucleophile
- ☐ D electrophile

(Total for Question 12 = 2 marks)

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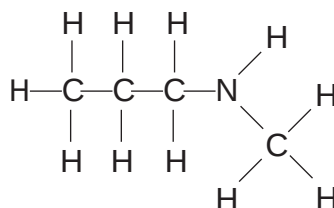
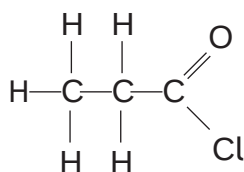
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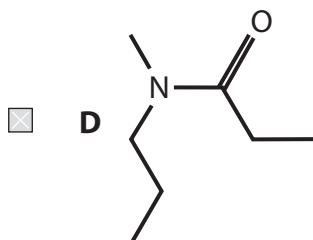
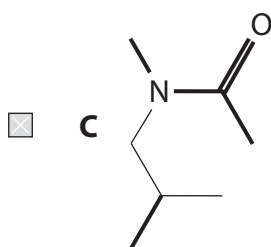
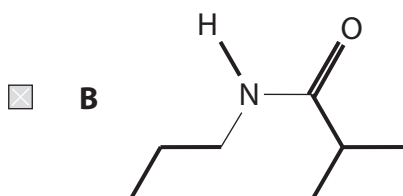
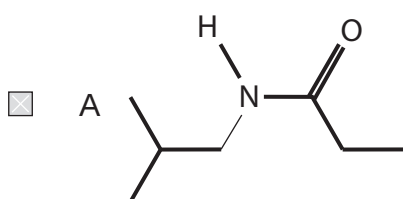
13 Propanoyl chloride and *N*-methylpropylamine react to form an amide and hydrogen chloride.

The structures of the reactants are shown.



(a) What is the structure of the amide formed?

(1)



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- (b) If 64.3 g of the amide is produced, what volume of HCl is formed at room temperature and pressure (r.t.p.)?

Assume the stoichiometry is 1 : 1.

1 mole of gas occupies 24.0 dm^3 at r.t.p.

(1)

- ☒ A 12.0 dm^3
☐ B 12.2 dm^3
☐ C 23.9 dm^3
☐ D 120 dm^3

(Total for Question 13 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

Answer **ALL** the questions. Write your answers in the spaces provided.

14 This question is about cell reactions involving chromium.

Use your Data Booklet when answering this question.

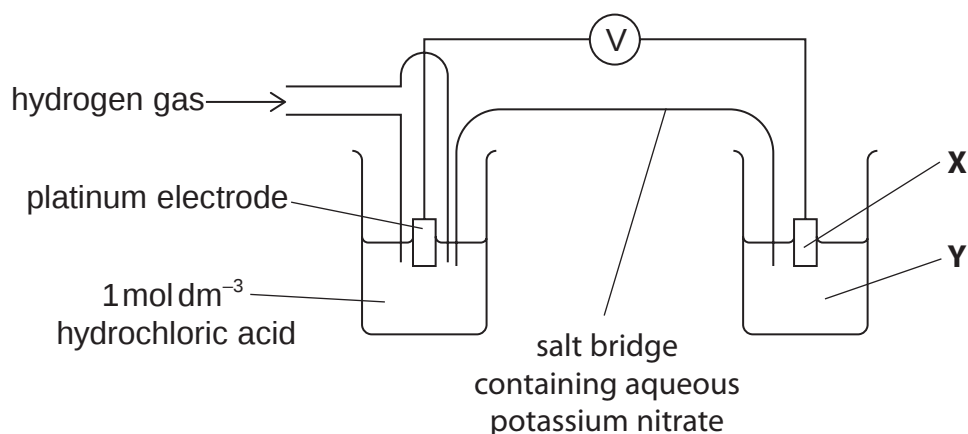
- (a) (i) Name the type of the forward reaction that is shown in the right-hand electrode systems in the Data Booklet.

(1)

- (ii) Name the series formed when the right-hand electrode systems are placed in order, most negative first.

(1)

- (b) A student set up the following apparatus to measure the standard electrode potential for right-hand electrode system 8 in your Data Booklet.



- (i) Identify **X** and **Y**.

(2)

X:

Y:

- (ii) Give **two** reasons why the initial reading on the voltmeter may differ from the stated value given in the Data Booklet.

(2)

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- (iii) The voltmeter is removed and the cell is allowed to run for one hour.

Explain the changes that would occur in the right-hand half-cell during this time.

(2)

- (c) (i) Explain, by calculating $E_{\text{cell}}^{\ominus}$ values, why Fe(II) is used to reduce Cr(VI) to Cr(III) but zinc is used to reduce Cr(VI) to Cr(II).

(4)

Numbers chosen of the right-hand electrode systems from the Data Booklet

Explanation

- (ii) State the essential condition required for these reactions to occur.

(1)

(Total for Question 14 = 13 marks)

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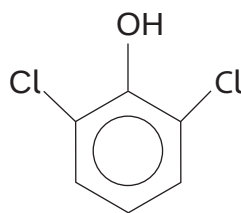
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- 15** 2,6-dichlorophenol is used for communication between ticks, small parasites that can infect animals including humans.

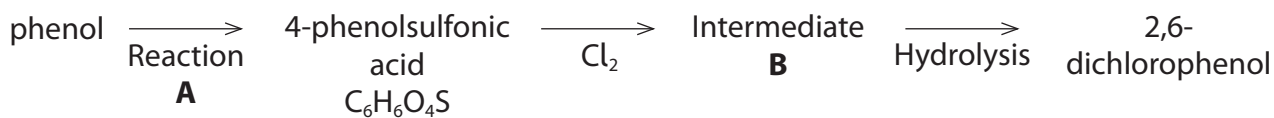


2,6-dichlorophenol

The compound can be synthesised in the laboratory from phenol.

4-phenolsulfonic acid is formed in Reaction **A**. This is then chlorinated. Hydrolysis of intermediate compound **B** removes the sulfonic acid group.

The reaction scheme is shown.



- (a) (i) The sulfonation of phenol is similar to the sulfonation of benzene. Suggest the reagent(s) required for Reaction **A**.

(1)

- (ii) Deduce the structure of intermediate compound **B**.

(1)



- (iii) Explain why the reaction of chlorine with phenol occurs under milder conditions than the reaction of chlorine with benzene.

(3)

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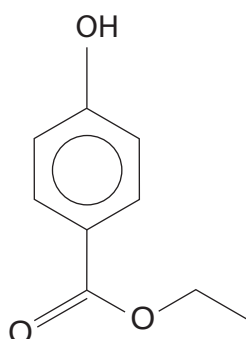
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- (b) An alternative synthesis of 2,6-dichlorophenol starts with compound **C**.

compound **C**

Compound **C** is chlorinated and hydrolysed and then the CO_2 group is removed (decarboxylation) to form 2,6-dichlorophenol.

Other than phenol, name the functional group present in compound **C**.

(1)

.....

- (c) Identify **three** factors that organic chemists would take into account when considering alternative methods for an organic synthesis.

(3)

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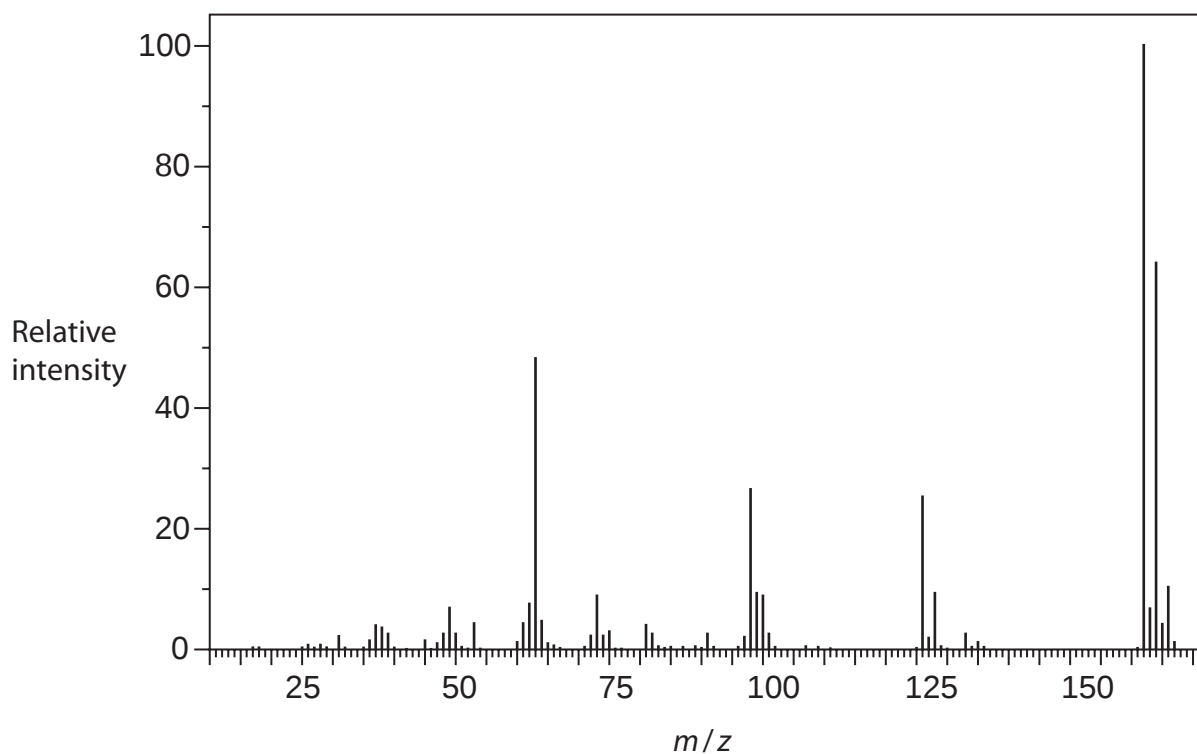
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(d) The mass spectrum of 2,6-dichlorophenol is shown.



(i) Explain the relative intensities of the peaks at m/z values of 162, 164 and 166.

(2)

(ii) Suggest why there is a corresponding set of peaks at m/z values of 163, 165 and 167.

(1)

(Total for Question 15 = 12 marks)



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- 16** Metal ions occur naturally in river water but near industrial plants the concentrations can reach toxic levels. Wastewater from a stainless steel electropolishing plant contains dangerous concentrations of transition metal ions as aqueous complexes.

Chemical precipitation can be used to remove these ions from the water.

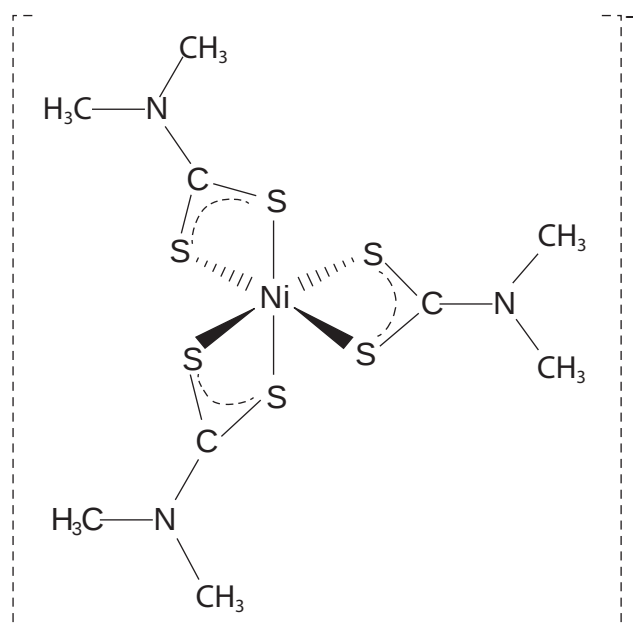
- (a) Complete the equation for the reaction of a laboratory reagent with aqueous Fe^{3+} ions to produce a precipitate.

Include state symbols in your answer.

(2)



- (b) Sodium dimethyldithiocarbamate, $(\text{CH}_3)_2\text{NCS}_2^- \text{Na}^+$, can also be used to precipitate metal ions from wastewater in acidic solutions. A representation of the molecule bonding with a nickel ion is shown.



- (i) Complete the table for the complex.

(3)

Charge on nickel ion	
Type of ligand	
Co-ordination number of the nickel ion	
Shape of metal complex around the nickel ion	

- (ii) Explain, using a balanced equation, why the formation of the dimethyldithiocarbamate complex from an aqueous solution of nickel ions is thermodynamically feasible.

State symbols are not required.

(2)

- (iii) When a 5 dm³ sample of wastewater was treated with excess **acidified** sodium dimethyldithiocarbamate, 245.0 mg of the dry precipitate $\text{H}^+[\text{Ni}((\text{CH}_3)_2\text{NCS}_2)_3]^-$ was formed.

Calculate the concentration, in mol dm⁻³, of nickel ions in the sample.

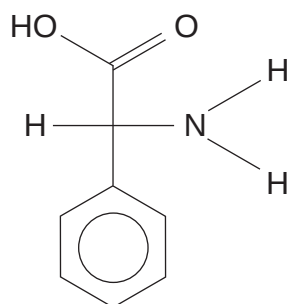
[Molar mass of dimethyldithiocarbamate ion = 120.2 g mol⁻¹]

(3)

(Total for Question 16 = 10 marks)



17 Phenylglycine is an amino acid which can be synthesised from benzene.

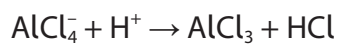
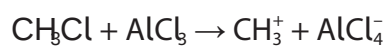


phenylglycine

- (a) The first step of the synthesis is the formation of methylbenzene, from benzene and chloromethane.

Draw the mechanism of this reaction.

Equations for the formation of the electrophile and regeneration of the catalyst are shown.



(3)

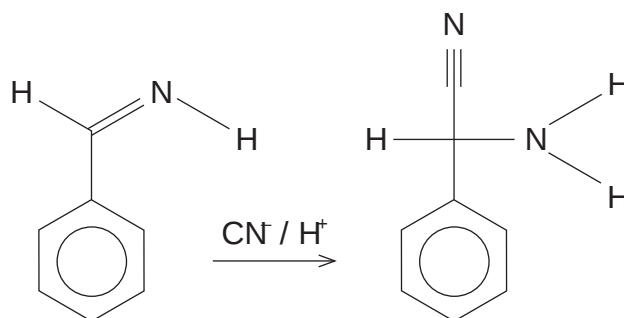
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(b) One of the steps in the synthesis is shown.



Explain, with reference to the mechanism, why this step in the reaction sequence will not produce a single isomer.

(3)

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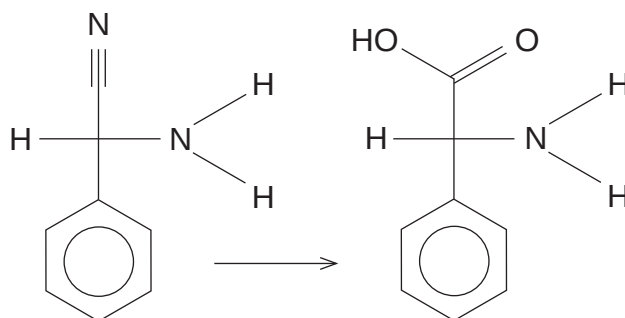
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(c) The final step in the synthesis is shown.



State the type of reaction, and the reagent(s) and conditions required.

(3)

Type

Reagent(s)

Conditions

(Total for Question 17 = 9 marks)



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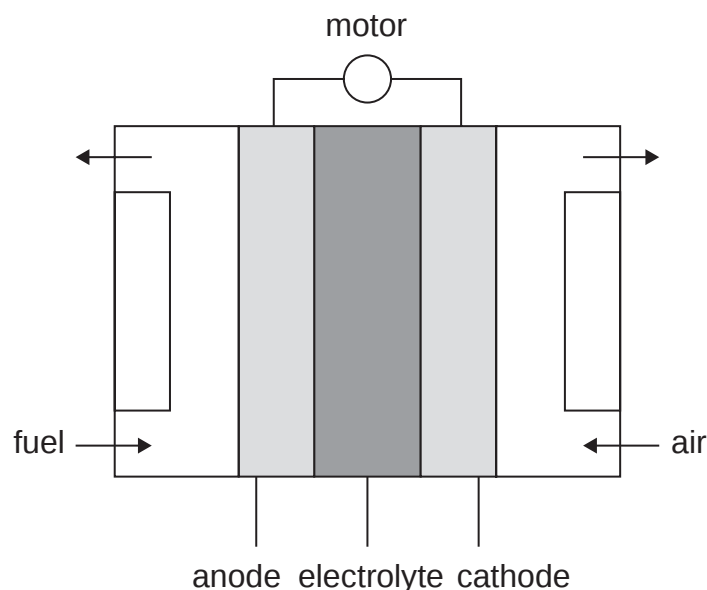
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- *18** Fuel cells are an alternative to internal combustion engines and batteries for powering vehicles.

A schematic diagram of a fuel cell is shown.



Explain how a fuel cell works, discussing their advantages and disadvantages. Use the acidic hydrogen–oxygen fuel cell as an example.

Include, in your answer, half-equations for the electrode reactions and an example of another fuel suitable for use in fuel cells.

$E^\ominus$ values and $E^\ominus_{\text{cell}}$ values are not required.

(6)

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(Total for Question 18 = 6 marks)

TOTAL FOR SECTION B = 50 MARKS



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SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

- 19** In recent years, there have been health and safety concerns over “liquitabs”. These are capsules which contain concentrated liquid detergents.

The soluble packaging breaks down upon contact with water during a laundry cycle to release the detergent.

Some liquitabs are small and colourful, which makes them attractive to young children who may be tempted to put them in their mouth or play with them. When moist, liquitabs can burst in a child’s hand, potentially irritating the eyes and skin. They can also dissolve quickly and may burst in a child’s mouth in a very short period of time. This allows the contents to escape quickly and if swallowed can cause severe breathing difficulties.

- (a) Identify the hazard symbol(s) that should be displayed on a box of liquitabs, using ticks (✓).

(1)

- (b) The capsule containing the detergent is often made from poly(ethenol) and its derivatives.

- (i) Draw the structure of poly(ethenol), showing three repeat units.

(2)

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- (ii) Use your structure from 19(b)(i) to calculate the percentage of hydroxyl groups by mass in the polymer.

(2)

- (iii) Explain why poly(ethenol) is soluble in water using your answers from 19(b)(i) and (ii).

(2)

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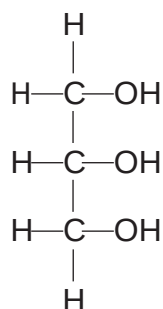
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- (c) In liquidab detergents, glycerol is added to the poly(ethenol).



glycerol

- (i) Give the IUPAC name for this molecule.

(1)

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- (ii) Suggest **one** way that the properties of poly(ethenol) will be improved by the use of glycerol, apart from any effect on solubility.

(1)

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- (iii) Glycerol is added to the polymer at 0.110%, by volume.

Calculate the number of moles of glycerol added to 1 tonne of poly(ethenol).

Data: 1 tonne = 1000 kg

density of glycerol: 1.26 g cm^{-3}

density of poly(ethenol): 1.19 g cm^{-3}

(4)

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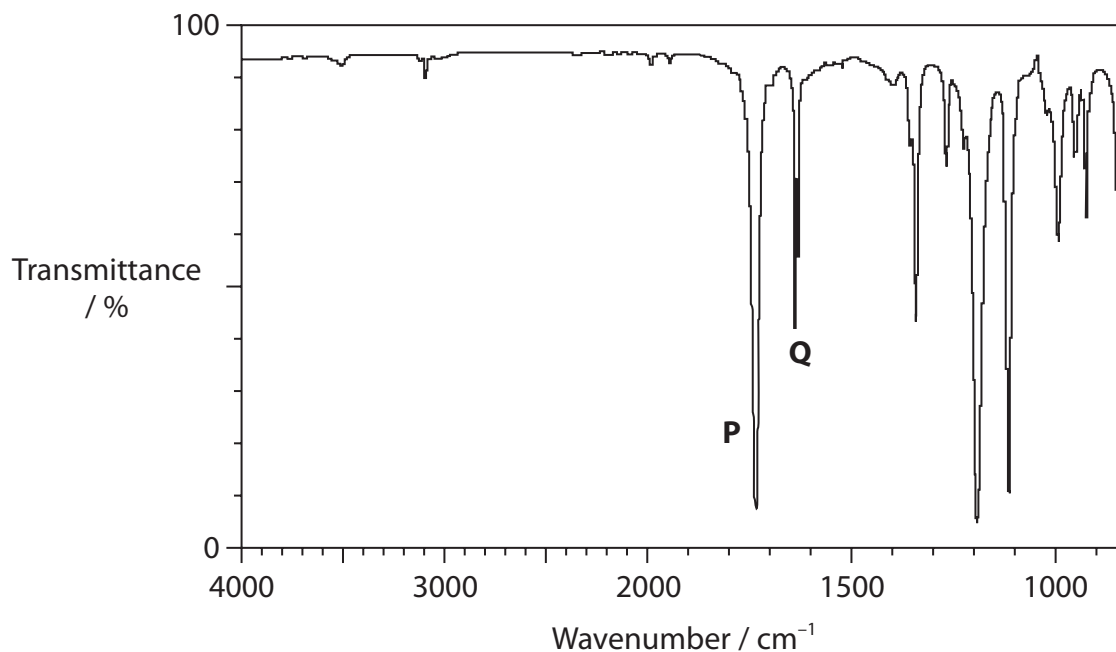


- (d) Poly(ethenol) is made from a polymer intermediate, rather than by polymerisation, as ethenol is unstable.

The polymer intermediate is prepared from a monomer, **X**.

When 1 mol of **X** is burned in excess oxygen, 95.6 dm³ of carbon dioxide (at r.t.p.) and 54.1 g of water are formed.

The infrared spectrum for the monomer is shown.



Use the information to deduce the displayed structure of the monomer of the polymer intermediate.

You must show your working and quote the relevant wavenumber ranges from your Data Booklet.

(5)

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- (e) Some hospitals use poly(ethenol) laundry bags instead of reusable, washable polyester or nylon bags.

State **two** advantages of using soluble poly(ethenol) laundry bags.

(2)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 MARKS



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36

* Lanthanide series

* Actinide series

Elements with atomic numbers 112-116 have been reported but not fully authenticated

140	Ce	cerium	58	141	Pr	praseodymium	59	144	Nd	neodymium	60	[147]	Pm	promethium	61	150	Sm	samarium	62	152	Eu	europium	63	157	Gd	gadolinium	64	159	Tb	terbium	65	163	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	mdendelevium	101	[254]	No	nobelium	102	[257]	Lr	lawrencium	103

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