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) | **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)

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

$$2KMnO_4 + 10FeSO_4 + 8H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 5Fe_2(SO_4)_3 + 8H_2O$$

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

(1)

	Iron	Manganese
☒ **A**	II → III	VII → II
☒ **B**	II → III	VII → IV
☒ **C**	III → II	II → VII
☒ **D**	III → II	III → IV

(b) A 25.00 cm^3 sample of $FeSO_4$ dissolved in acid required 22.50 cm^3 of 0.100 mol dm^{-3} $KMnO_4$ for complete reaction.

What is the concentration of the $FeSO_4$ solution?

(1)

☒ **A** 0.011 mol dm^{-3}

☒ **B** 0.100 mol dm^{-3}

☒ **C** 0.450 mol dm^{-3}

☒ **D** 0.900 mol dm^{-3}

(Total for Question 3 = 2 marks)

4 The emf, $E^{\ominus}_{cell}$, 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** 2.70 V

☒ **B** 2.72 V

☒ **C** 2.74 V

☒ **D** 2.85 V

(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 $E^{\ominus}_{cell}$?

Use your Data Booklet.

☒ **A** $Zn(s) \mid Zn^{2+}(aq) \parallel Ni^{2+}(aq) \mid Ni(s)$

☒ **B** $Zn^{2+}(aq) \mid Zn(s) \parallel Ni(s) \mid Ni^{2+}(aq)$

☒ **C** $Ni(s) \mid Ni^{2+}(aq) \parallel Zn^{2+}(aq) \mid Zn(s)$

☒ **D** $Ni^{2+}(aq) \mid Ni(s) \parallel Zn(s) \mid Zn^{2+}(aq)$

(Total for Question 5 = 1 mark)

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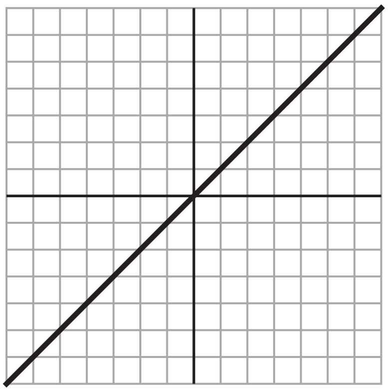
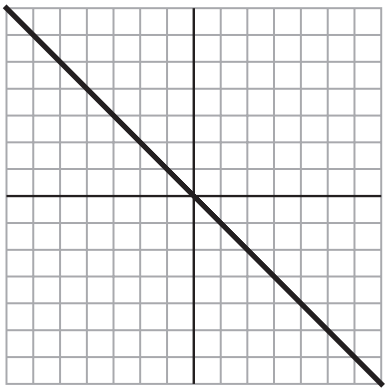
6 Which graph shows the relationship between $E^{\ominus}_{cell}$ plotted on the x-axis and ΔS_{total} on the y-axis for any electrochemical system?

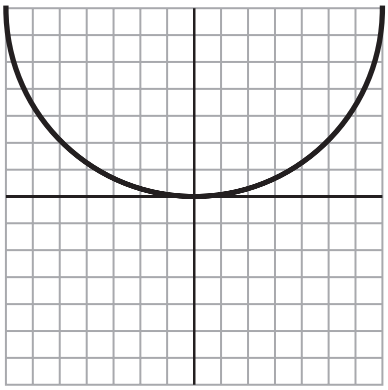
☒ **A**



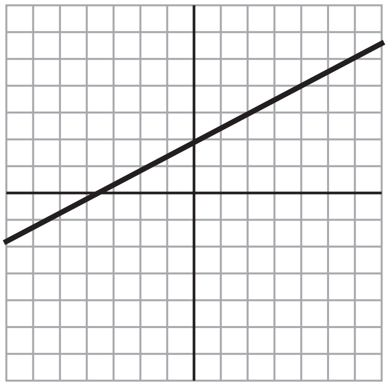
☒ **B**



☒ **C**



☒ **D**



(Total for Question 6 = 1 mark)

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** $HNO_3 + H_2SO_4 \rightarrow NO_2^+ + SO_4^{2-} + H_3O^+$

☒ **B** $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$

☒ **C** $HNO_2 + 2H_2SO_4 + H_2O \rightarrow NO_3^+ + 2HSO_4^- + 5H^+$

☒ **D** $HNO_3 + 3H_2SO_4 + OH^- \rightarrow NO_2 + 3HSO_4^- + H_3O^+ + H_2O$

(Total for Question 8 = 1 mark)

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

$$C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$$

[M_r values: C_6H_5OH = 94.0 Br_2= 159.8 $C_6H_2Br_3OH$ = 330.7 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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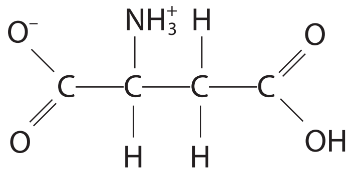
10 Aspartic acid is a naturally-occurring amino acid.

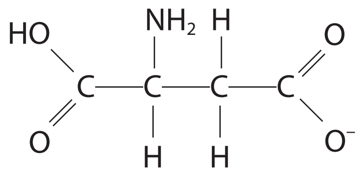
(a) Which form of aspartic acid is formed at pH 12?

(1)

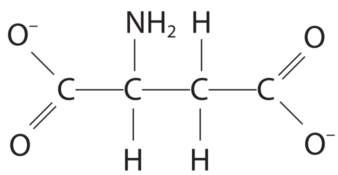
☒ **A**



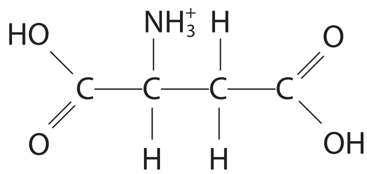
☒ **B**



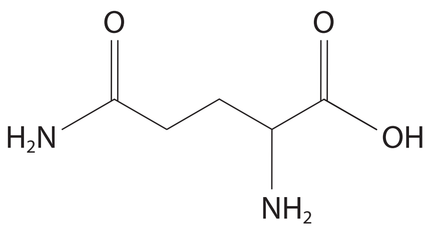
☒ **C**



☒ **D**



(b) Glutamine is shown.



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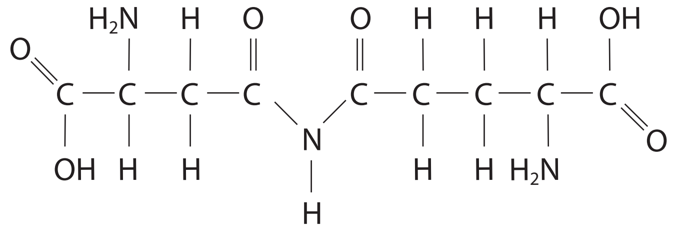
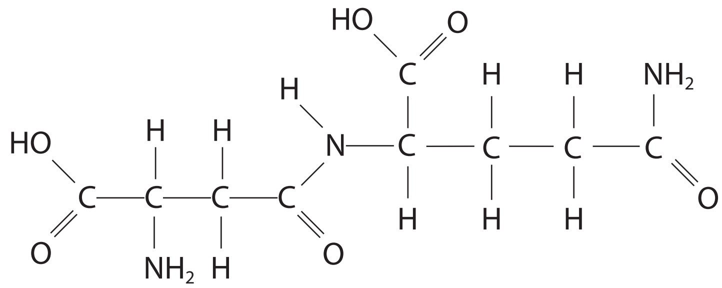
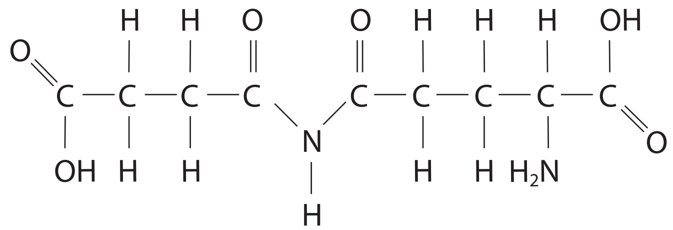
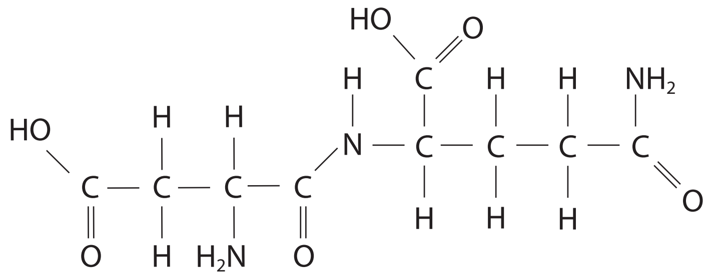
(i) Which is a correct structure when aspartic acid forms a dipeptide with glutamine?

(1)

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(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)

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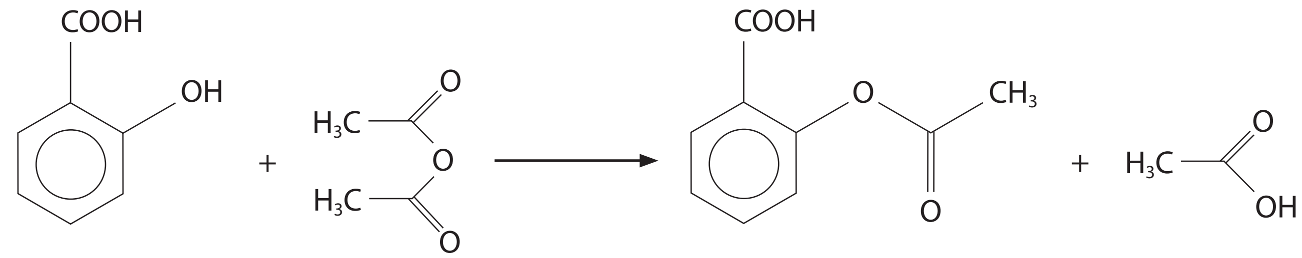
PMT

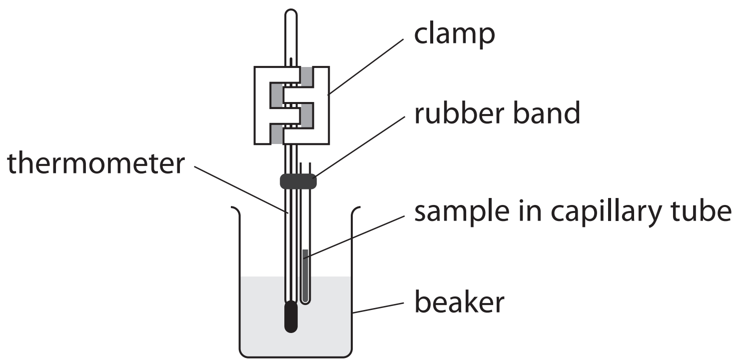
11 A student prepared a sample of aspirin. The equation for the reaction is shown.



2-hydroxybenzoic acid — ethanoic anhydride — aspirin — ethanoic acid

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)

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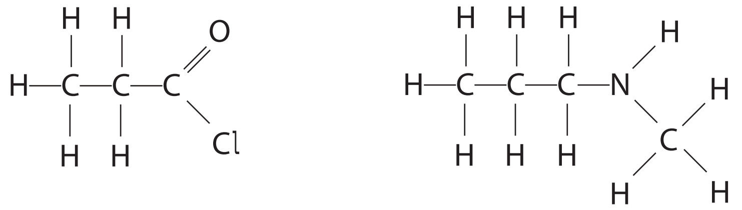
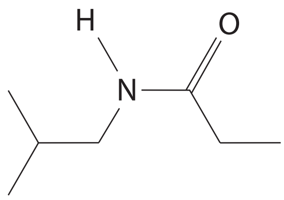
13 Propanoyl chloride and *N*-methylpropylamine react to form an amide and hydrogen chloride.

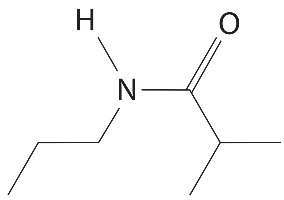
The structures of the reactants are shown.

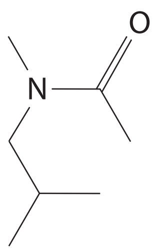


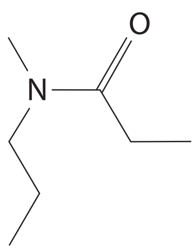
(a) What is the structure of the amide formed?

(1)

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

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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

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)

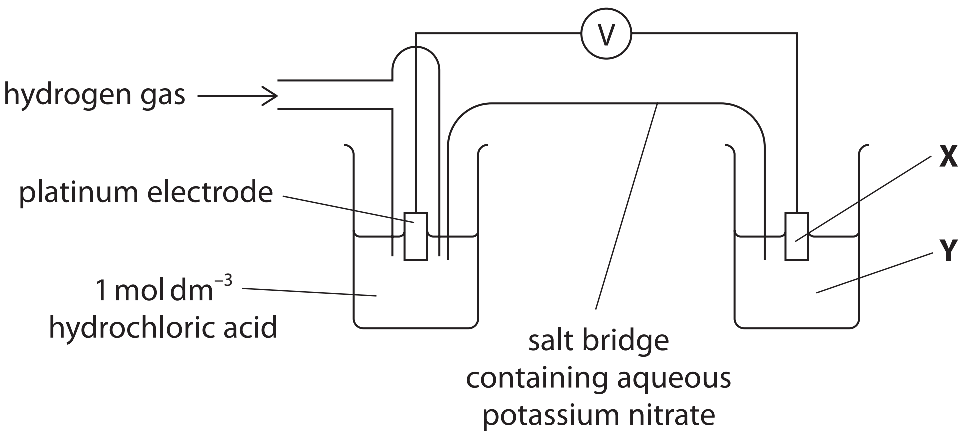
....

(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)

....

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....

....

....

....

....

(c) (i) Explain, by calculating $E^{\ominus}_{cell}$ 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.

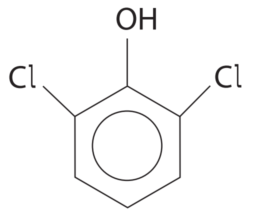
(1)

....

(Total for Question 14 = 13 marks)

PMT

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.

phenol —(Reaction **A**)→ 4-phenolsulfonic acid $C_6H_6O_4S$ —(Cl_2)→ Intermediate **B** —(Hydrolysis)→ 2,6-dichlorophenol

(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)

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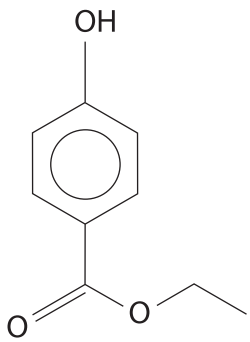
(iii) Explain why the reaction of chlorine with phenol occurs under milder conditions than the reaction of chlorine with benzene.

(3)

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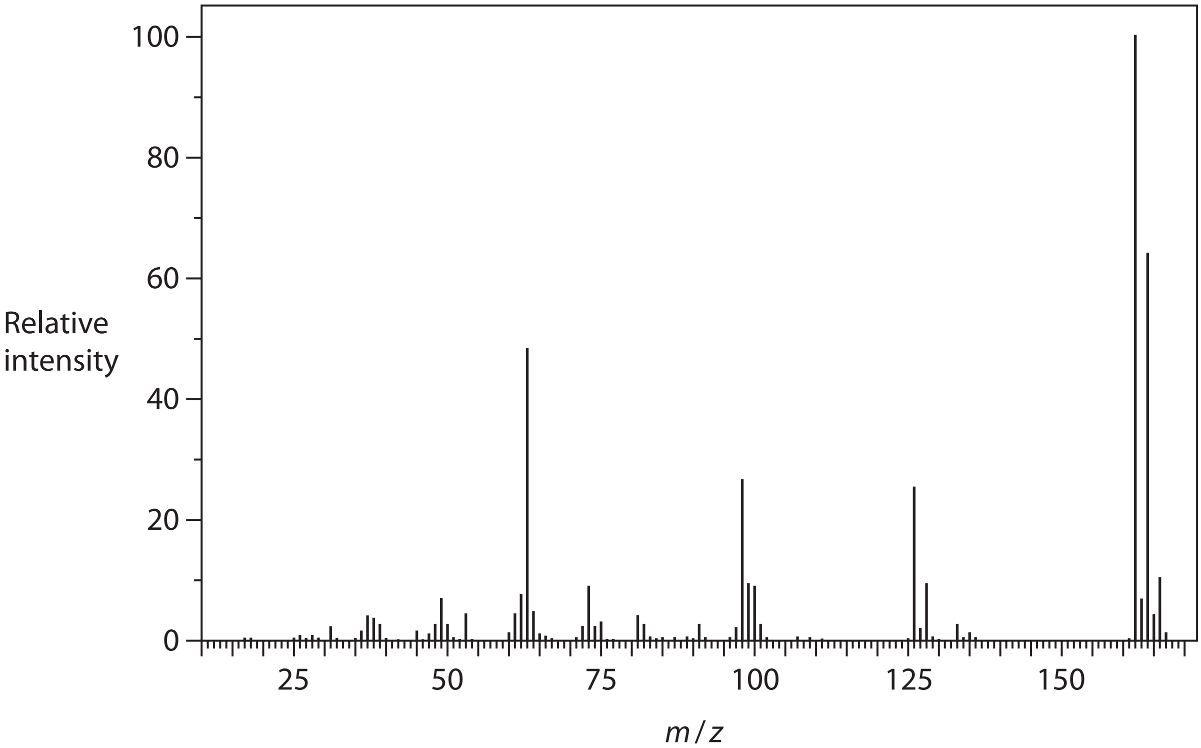
(d) The mass spectrum of 2,6-dichlorophenol is shown.



(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.

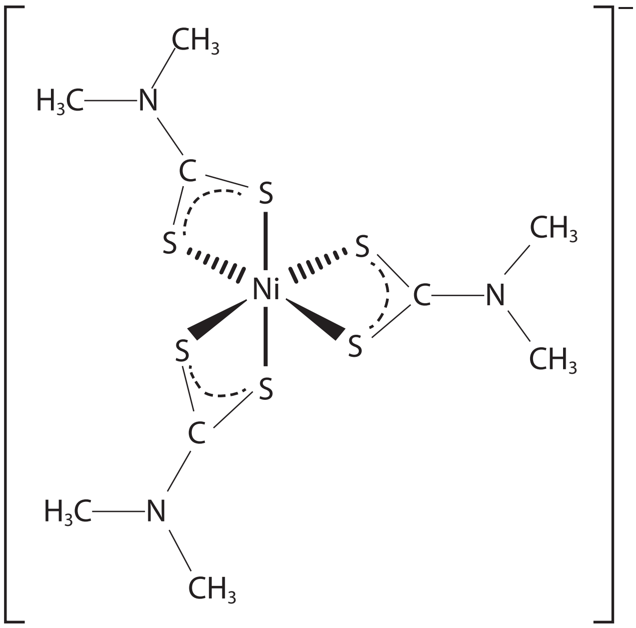
(a) Complete the equation for the reaction of a laboratory reagent with aqueous Fe^{3+} ions to produce a precipitate.

Include state symbols in your answer.

(2)

$[Fe(H_2O)_6]^{3+}(aq)$ + $\rightarrow$

(b) Sodium dimethyldithiocarbamate, $(CH_3)_2NCS_2^-Na^+$, 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	

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(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 dm^3 sample of wastewater was treated with excess **acidified** sodium dimethyldithiocarbamate, 245.0 mg of the dry precipitate $H^+[Ni((CH_3)_2NCS_2)_3]^-$ was formed.

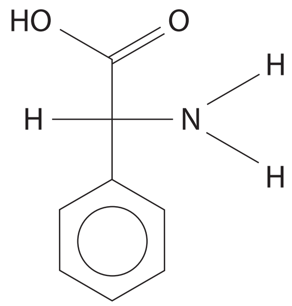
Calculate the concentration, in mol dm^{-3}, of nickel ions in the sample.

[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.

$$CH_3Cl + AlCl_3 \rightarrow CH_3^+ + AlCl_4^-$$
$$AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$$

(3)

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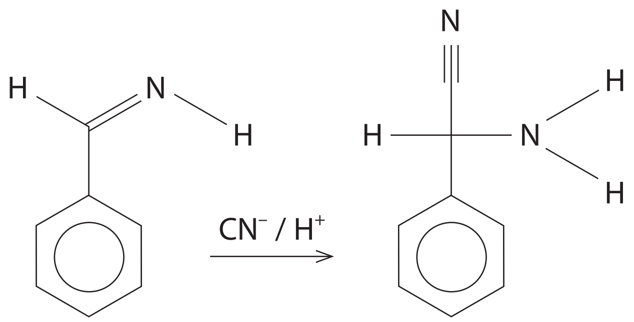
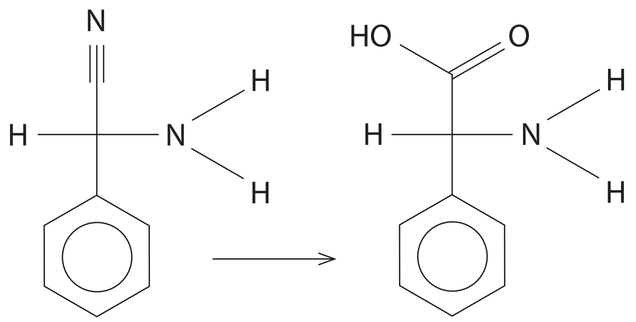
(b) One of the steps in the synthesis is shown.



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

(3)

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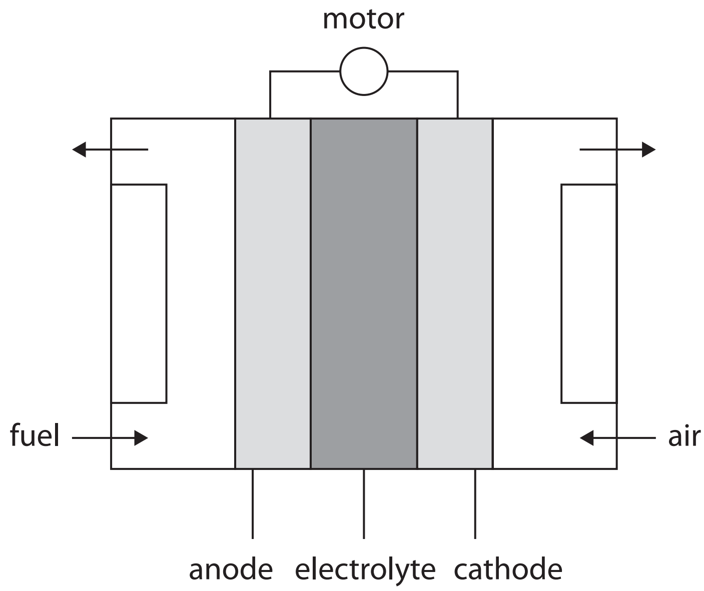
***18** Fuel cells are an alternative to internal combustion engines and batteries for powering vehicles.

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

(6)

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P 7 5 7 8 2 A 0 2 6 3 6

(Total for Question 18 = 6 marks)

TOTAL FOR SECTION B = 50 MARKS

SECTION C

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

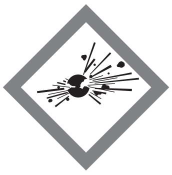
19 In recent years, there have been health and safety concerns over "liquitabs". These are capsules which contain concentrated liquid detergents.

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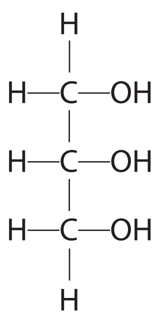
(ii) Use your structure from 19(b)(i) to calculate the percentage of hydroxyl groups by mass in the polymer.

(2)

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

(2)

(c) In liquitab 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.

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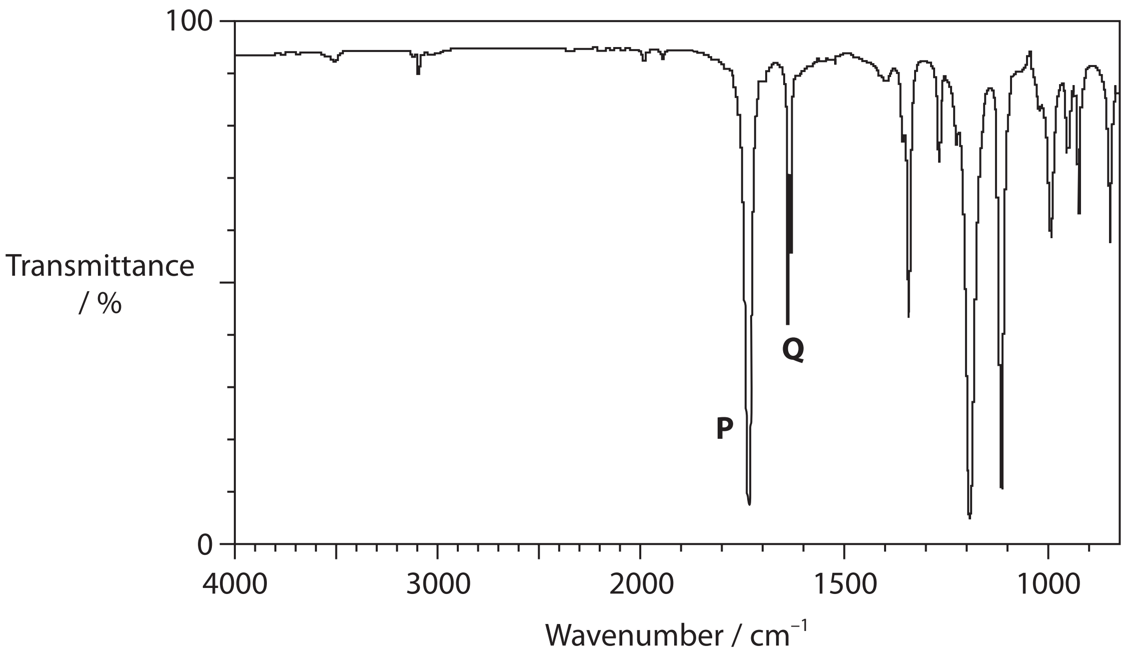
(d) Poly(ethenol) is made from a polymer intermediate, rather than by polymerisation, as ethenol is unstable.

The polymer intermediate is prepared from a monomer, **X**.
When 1 mol of **X** is burned in excess oxygen, 95.6 dm^3 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.

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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)

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

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The Periodic Table of Elements

Key

relative atomic mass **atomic symbol** name atomic (proton) number

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **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							

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

* Lanthanide series	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
* Actinide series	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

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