Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Wednesday 7 June 2023

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

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 that 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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P 7 1 9 4 3 A 0 1 3 6

Pearson

SECTION A

Answer ALL the questions in this section.

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

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The equation for a redox reaction is shown.

$$2V^{2+}(aq) + Cu^{2+}(aq) \rightarrow 2V^{3+}(aq) + Cu(s)$$

What is the cell diagram for this reaction?

☒ **A** $V(s) \mid V^{3+}(aq), V^{2+}(aq) \mid\mid Cu(s) \mid Cu^{2+}(aq)$

☒ **B** $V(s) \mid V^{2+}(aq), V^{3+}(aq) \mid\mid Cu^{2+}(aq) \mid Cu(s)$

☒ **C** $Pt(s) \mid V^{3+}(aq), V^{2+}(aq) \mid\mid Cu(s) \mid Cu^{2+}(aq)$

☒ **D** $Pt(s) \mid V^{2+}(aq), V^{3+}(aq) \mid\mid Cu^{2+}(aq) \mid Cu(s)$

(Total for Question 1 = 1 mark)

2 Some standard electrode potentials are shown.

Right-hand electrode system	$E^{\ominus}$ / V
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	−2.37
$Ce^{3+} + 3e^- \rightleftharpoons Ce$	−2.33
$Mn^{2+} + 2e^- \rightleftharpoons Mn$	−1.19
$Mn^{3+} + e^- \rightleftharpoons Mn^{2+}$	+1.49
$Ce^{4+} + e^- \rightleftharpoons Ce^{3+}$	+1.70

Which reaction is thermodynamically feasible?

☒ **A** $2Ce + 3Mg^{2+} \rightarrow 2Ce^{3+} + 3Mg$

☒ **B** $4Ce^{3+} \rightarrow Ce + 3Ce^{4+}$

☒ **C** $3Mn^{2+} \rightarrow Mn + 2Mn^{3+}$

☒ **D** $Mg + 2Ce^{4+} \rightarrow Mg^{2+} + 2Ce^{3+}$

(Total for Question 2 = 1 mark)

3 In a chemical reaction, $E^{\ominus}_{cell}$ is **directly** proportional to

- ☒ **A** K_c
- ☒ **B** $\Delta_r H^{\ominus}$
- ☒ **C** $\Delta S^{\ominus}_{system}$
- ☒ **D** $\Delta S^{\ominus}_{total}$

(Total for Question 3 = 1 mark)

4 For the reaction shown, $E^{\ominus}_{cell} = +0.89\,V$.

$$4V^{3+}(aq) + O_2(g) + 2H_2O(l) \rightarrow 4VO^{2+}(aq) + 4H^+(aq)$$

Which statement can be deduced from this information only?

- ☒ **A** the reaction will **not** occur under any conditions
- ☒ **B** the reactants are kinetically stable with respect to the products
- ☒ **C** the reactants are thermodynamically unstable with respect to the products
- ☒ **D** an aqueous solution of V^{3+} will oxidise rapidly on standing in air

(Total for Question 4 = 1 mark)

5 Which reaction occurs at the **negative** electrode in a hydrogen-oxygen fuel cell?

- ☒ **A** $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$
- ☒ **B** $2H^+ + 2e^- \rightarrow H_2$
- ☒ **C** $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
- ☒ **D** $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$

(Total for Question 5 = 1 mark)

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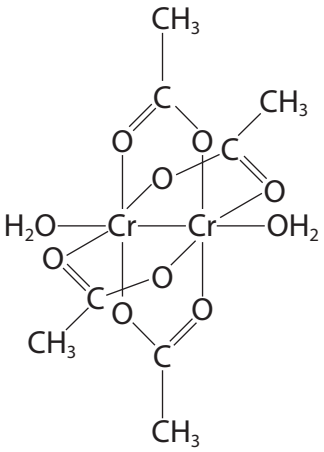
6 Which electronic configuration is correct?

- ☒ **A** Ti^{2+} $[Ar]4s^2$
- ☒ **B** Cr $[Ar]3d^4 4s^2$
- ☒ **C** Fe^{3+} $[Ar]3d^3 4s^2$
- ☒ **D** Cu $[Ar]3d^{10} 4s^1$

(Total for Question 6 = 1 mark)

7 The structure of the complex $Cr_2(CH_3CO_2)_4(H_2O)_2$ is shown.



What is the coordination number of chromium in this complex?

- ☒ **A** two
- ☒ **B** four
- ☒ **C** six
- ☒ **D** twelve

(Total for Question 7 = 1 mark)

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

8 Which complex contains **only** monodentate ligands?

- ☒ **A** $[Fe(CN)_6]^{4-}$
- ☒ **B** $[Cr(C_2O_4)_3]^{3-}$
- ☒ **C** $[Ni(EDTA)]^{2-}$
- ☒ **D** $[Co(NH_2CH_2CH_2NH_2)_2Cl_2]$

(Total for Question 8 = 1 mark)

9 Which complex has a ligand-metal-ligand bond angle of 109.5°?

- ☒ **A** $[CuCl_4]^{2-}$
- ☒ **B** $[Fe(EDTA)]^{-}$
- ☒ **C** $[Ag(NH_3)_2]^{+}$
- ☒ **D** $[Pt(NH_3)_2Cl_2]$

(Total for Question 9 = 1 mark)

10 Which ion is **not** blue?

- ☒ **A** VO^{2+}
- ☒ **B** $[Co(H_2O)_6]^{2+}$
- ☒ **C** $[Cr(H_2O)_6]^{2+}$
- ☒ **D** $[Cu(H_2O)_6]^{2+}$

(Total for Question 10 = 1 mark)

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11 Which equation shows a **redox** reaction in which the solution turns yellow?

☒ **A** $Fe + 2HCl \rightarrow FeCl_2 + H_2$

☒ **B** $VO_3^- + 2H^+ \rightarrow VO_2^+ + H_2O$

☒ **C** $Cr_2O_7^{2-} + 2OH^- \rightarrow 2CrO_4^{2-} + H_2O$

☒ **D** $2Cr(OH)_3 + 3H_2O_2 + 4KOH \rightarrow 2K_2CrO_4 + 8H_2O$

(Total for Question 11 = 1 mark)

12 Aqueous ammonia is added in **excess** to an aqueous solution of Cu^{2+}.

What is the equation for the overall reaction?

☒ **A** $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Cu(H_2O)_4(OH)_2] + 2NH_4^+$

☒ **B** $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Cu(NH_3)_2(H_2O)_4]^{2+} + 2H_2O$

☒ **C** $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$

☒ **D** $[Cu(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Cu(NH_3)_6]^{2+} + 6H_2O$

(Total for Question 12 = 1 mark)

13 Which equation shows the formation of a precipitate?

☒ **A** $[Zn(OH)_4]^{2-} + 2H_3O^+ \rightarrow [Zn(H_2O)_4(OH)_2]$

☒ **B** $[Zn(H_2O)_6]^{2+} + 4OH^- \rightarrow [Zn(OH)_4]^{2-} + 6H_2O$

☒ **C** $[Cr(H_2O)_3(OH)_3] + 3H_3O^+ \rightarrow [Cr(H_2O)_6]^{3+} + 3H_2O$

☒ **D** $[Cr(H_2O)_3(OH)_3] + 3OH^- \rightarrow [Cr(OH)_6]^{3-} + 3H_2O$

(Total for Question 13 = 1 mark)

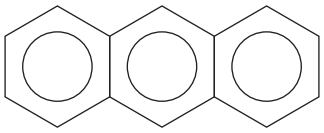
Use this space for any rough working. Anything you write in this space will gain no credit.

14 What is the sequence of oxidation number changes for vanadium when V_2O_5 is used in the contact process?

- ☒ **A** +2 → +1 → +2
- ☒ **B** +2 → +5 → +2
- ☒ **C** +5 → +4 → +5
- ☒ **D** +5 → +6 → +5

(Total for Question 14 = 1 mark)

15 What is the **total** number of delocalised electrons in anthracene?



anthracene

- ☒ **A** 6
- ☒ **B** 10
- ☒ **C** 14
- ☒ **D** 18

(Total for Question 15 = 1 mark)

16 Which statement explains why bromine reacts more readily with phenol than with benzene?

- ☒ **A** the O—H bond in phenol is polar
- ☒ **B** the oxygen atom in phenol is very electronegative
- ☒ **C** a lone pair of electrons on oxygen in phenol is delocalised into the ring
- ☒ **D** the electron density in the ring is greater in benzene than in phenol

(Total for Question 16 = 1 mark)

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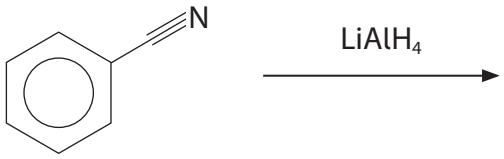
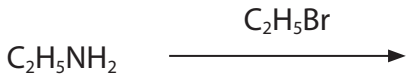
17 Which reaction can form a **secondary** amine?

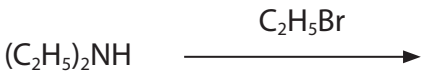
☒ **A**



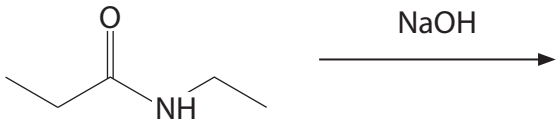
☒ **B**



☒ **C**



☒ **D**



(Total for Question 17 = 1 mark)

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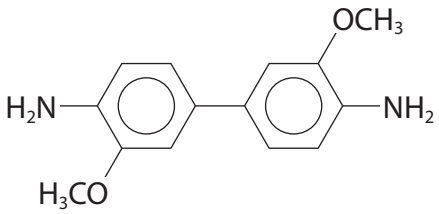
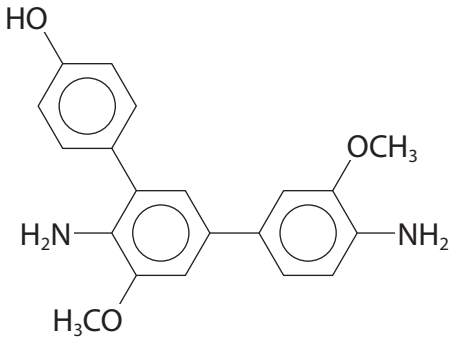
18 Compound **X** reacts with **excess** nitrous acid, followed by coupling with **excess** phenol to form an azo dye.



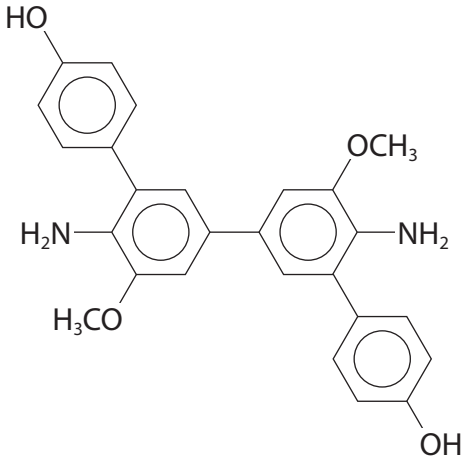
compound **X**

What is the structure of the azo dye?

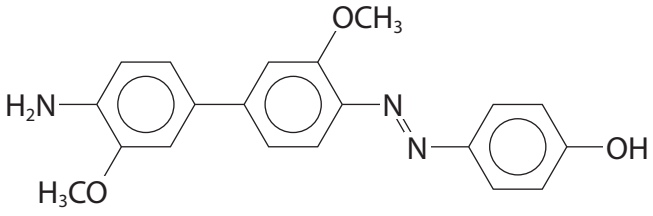
☒ **A**



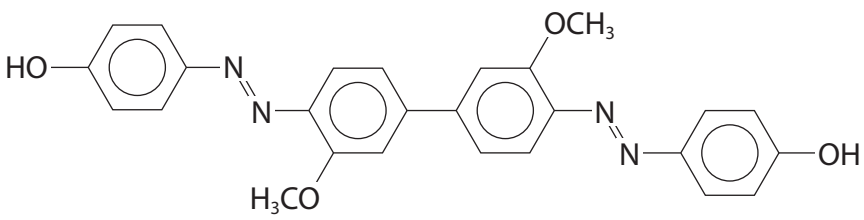
☒ **B**



☒ **C**



☒ **D**

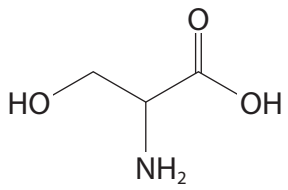


(Total for Question 18 = 1 mark)

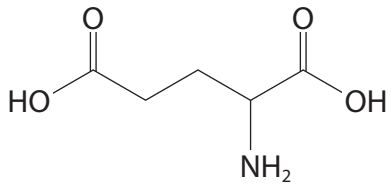
19 Four amino acids are dissolved in deionised water to form separate 0.05 mol dm^{-3} solutions.

Which amino acid will give the solution with the **lowest** pH?

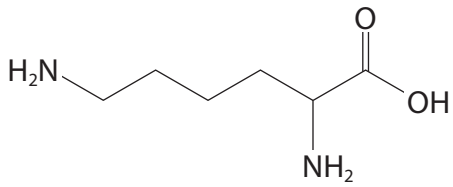
☒ **A**



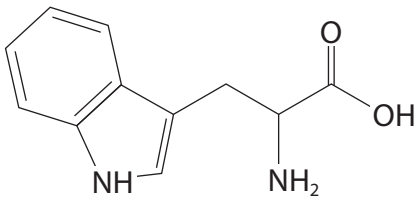
☒ **B**



☒ **C**



☒ **D**



(Total for Question 19 = 1 mark)

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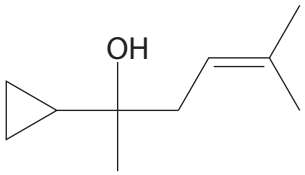
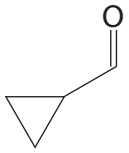
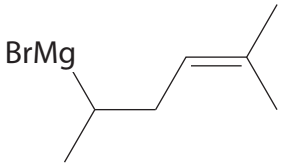
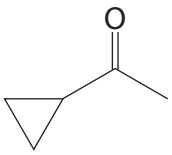
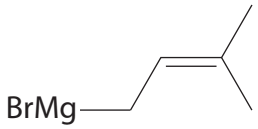
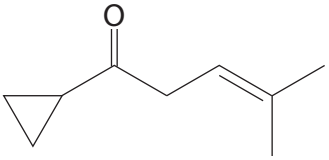
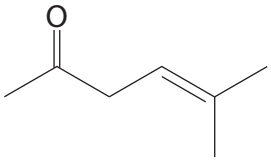
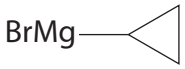
20 Which carbonyl compound and Grignard reagent would **not** react to form compound **Y**?



compound **Y**

	Carbonyl compound	Grignard reagent
☒ **A**		
☒ **B**		
☒ **C**		$BrMgCH_3$
☒ **D**		

(Total for Question 20 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

21 This question is about mercury, Hg, and its compounds.

Mercury is a liquid element in the same group of the Periodic Table as zinc.

The electronic configuration of mercury is $[Xe]4f^{14}5d^{10}6s^2$.

(a) Mercury forms compounds in either the +1 or +2 oxidation states.

Explain why mercury is classified as a d-block element but is **not** a transition element.

(3)

(b) Mercury reacts with nitric acid to form an aqueous solution of $Hg(NO_3)_2$ and nitrogen monoxide gas.

The **unbalanced** equation is shown.

$$Hg(l) + HNO_3(aq) \rightarrow Hg(NO_3)_2(aq) + NO(g) + H_2O(l)$$

(i) Explain, using oxidation numbers, why this is a redox reaction.

(2)

.....

.....

.....

.....

.....

(ii) Deduce the **ionic** half-equations for this reaction.
State symbols are not required.

(2)

(iii) Complete the equation for this reaction by adding the stoichiometric coefficients.

(1)

..... $Hg(l)$ + ... $HNO_3(aq)$ $\rightarrow$ ..... $Hg(NO_3)_2(aq)$ + ... $NO(g)$ + ... $H_2O(l)$

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(c) Mercury(II) fulminate, $Hg(CNO)_2$, is an explosive.

(i) It is produced in the reaction between $Hg(NO_3)_2$ and ethanol. The other products of the reaction are ethanal and water.

Write the equation for the reaction of one mole of $Hg(NO_3)_2$ with ethanol to form mercury(II) fulminate.
State symbols are not required.

(2)

(ii) $Hg(CNO)_2$ decomposes as shown.

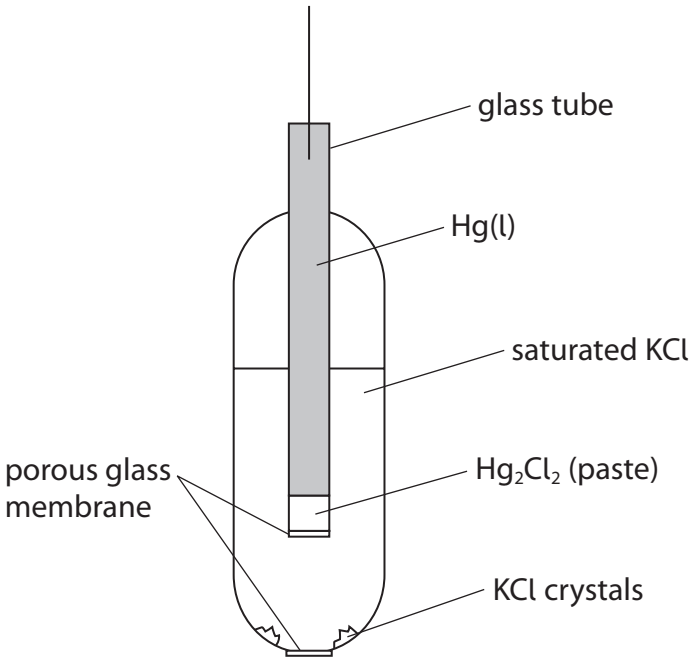
$$3Hg(CNO)_2(s) \rightarrow Hg(CN)_2(s) + 2Hg(s) + 2CO_2(g) + 2CO(g) + 2N_2(g)$$

Calculate the **total** volume, in cm^3, of gas produced when 1.00 g of $Hg(CNO)_2$ decomposes at room temperature and pressure.

(3)

(d) Mercury(I) chloride, Hg_2Cl_2, is also known as calomel.

A saturated calomel electrode may be used as an alternative to the standard hydrogen electrode.



The half-equation for the calomel electrode is

$$Hg_2Cl_2(s) + 2e^- \rightleftharpoons 2Hg(l) + 2Cl^-(aq)$$

The standard electrode potential of the calomel electrode is $E^{\ominus} = +0.24\,V$.

(i) Suggest why KCl crystals are needed in the outer tube of the electrode.

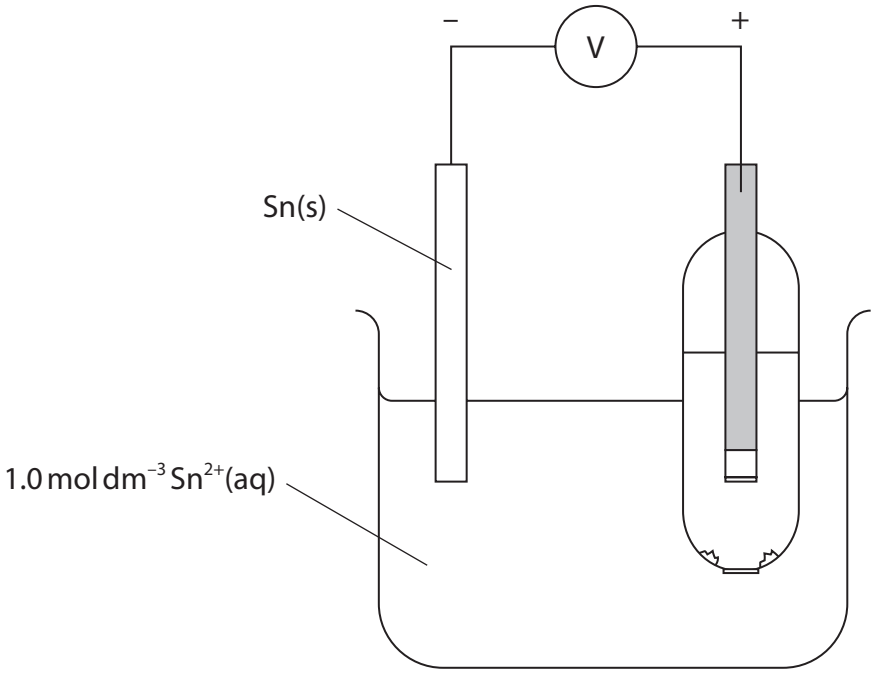
(1)

.....

.....

.....

(ii) A calomel electrode was used to measure the standard electrode potential of the $Sn^{2+}(aq) \mid Sn(s)$ half-cell.



The reading on the voltmeter in this cell was +0.37 V.

Deduce the standard electrode potential for the $Sn^{2+}(aq) \mid Sn(s)$ half-cell.

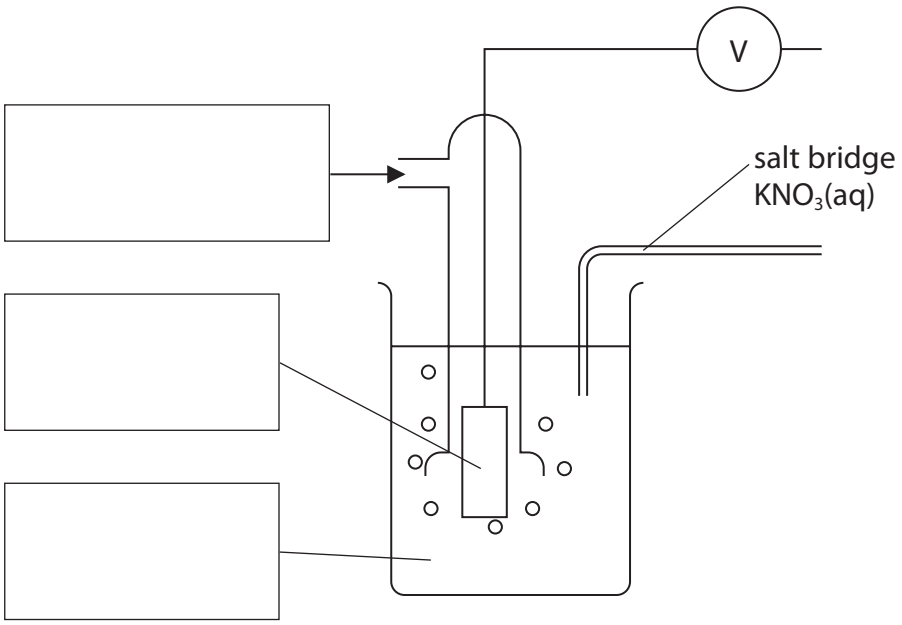
(1)

(iii) Write the overall equation for the cell reaction.

(1)

(iv) Add labels to complete the diagram of a standard hydrogen electrode. Include details of any essential conditions.

(3)



(v) Suggest **one** advantage of using a calomel electrode, in place of a standard hydrogen electrode, when measuring a cell potential.

(1)

(Total for Question 21 = 20 marks)

22 The amount of calcium ethanedioate, CaC_2O_4, present in a sample of spinach is determined by redox titration.

11.4 g of spinach leaves are stirred in 50.0 cm^3 of a warm acidified solution of 0.0100 mol dm^{-3} potassium manganate(VII), $KMnO_4$, oxidising all the ethanedioate ions, $C_2O_4^{2-}$.

$$16H^+ + 2MnO_4^- + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

The excess manganate(VII) ions, MnO_4^-, are then titrated with an acidified solution of 0.0500 mol dm^{-3} iron(II) sulfate, $FeSO_4$.

$$5Fe^{2+} + 8H^+ + MnO_4^- \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$$

25.95 cm^3 of iron(II) sulfate solution was needed for complete reaction.

Calculate the percentage by mass of CaC_2O_4 present in the spinach leaves.
Give your answer to an appropriate number of significant figures.

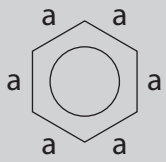
(Total for Question 22 = 6 marks)

***23** Some thermochemical, X-ray diffraction and bromination information on benzene and cyclohexene is shown.

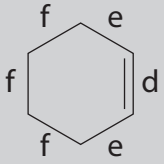
Thermochemical data

Compound	Enthalpy of hydrogenation / kJ mol^{-1}
benzene	–208
cyclohexene	–120

X-ray diffraction data



Benzene bond	a
Bond length / pm	139



Cyclohexene bond	d	e	f
Bond length / pm	129	150	153

Bromination

Compound	Reaction conditions	Organic product
benzene	$FeBr_3$, heat	bromobenzene
cyclohexene	room temperature	1,2-dibromocyclohexane

Explain how **all** this information provides evidence that the electrons in the π-bonds of benzene are delocalised.

(6)

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DO NOT WRITE IN THIS AREA

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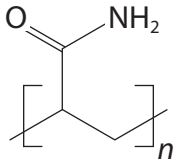
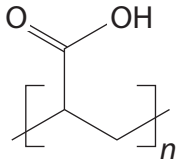
(Total for Question 23 = 6 marks)

24 This question is about polymers.

(a) Polyacrylamide (PAM) and polyacrylic acid (PAA) are water-absorbent addition polymers.

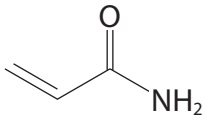


PAM



PAA

(i) PAM is made from the acrylamide monomer.



acrylamide

Give the IUPAC name for acrylamide.

(1)

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(ii) Explain why PAM is able to absorb **large** amounts of water.
Include a diagram in your answer.

(3)

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DO NOT WRITE IN THIS AREA

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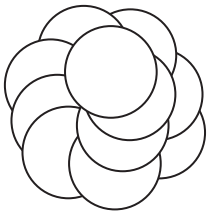
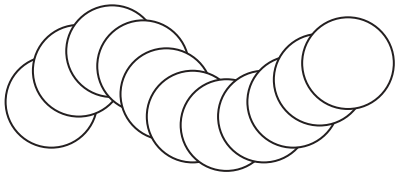
(iii) The structure of PAA in aqueous solution is pH-dependent.

Below pH 4, the structure of PAA is compact due to the formation of intramolecular hydrogen bonds.

Above pH 8, PAA has an open coil structure.



compact structure
below pH 4



open coil structure
above pH 8

Suggest why PAA exists as an open coil structure above pH 8.

(2)

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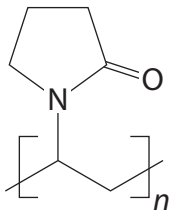
DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

(b) Polyvinylpyrrolidone (PVP) is an addition polymer used in the pharmaceutical industry. The average molar mass of PVP is 90 000 g mol^{-1}.



PVP

(i) Draw the structure of the vinylpyrrolidone monomer used to make PVP.

(1)

(ii) Calculate the number of monomers needed to make one molecule of PVP polymer with a molar mass of 90 000 g mol^{-1}.

Give your answer to the nearest whole number.

(2)

(iii) A 740 mg tablet of a painkiller contains 4.0 % PVP by mass.

Calculate the number of molecules of PVP polymer in the tablet.

(3)

(c) All types of nylon are condensation polymers.

(i) State what is meant by the term **condensation polymer**.

(2)

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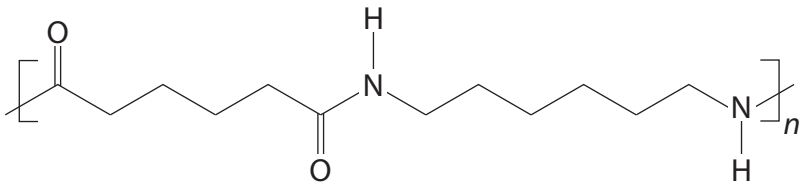
(ii) The structure of nylon 6,6 is shown.



nylon 6,6

Nylon 6,6 is made from two monomers.

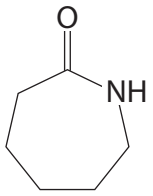
Deduce the **structural** formulae of these two monomers.

(2)

structural formula of monomer 1

structural formula of monomer 2

(iii) Caprolactam can be directly converted to give a different polymer, nylon 6, in a ring-opening polymerisation reaction.



caprolactam

Draw **two** repeat units of nylon 6.

(2)

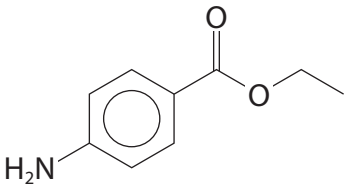
(Total for Question 24 = 18 marks)

TOTAL FOR SECTION B = 50 MARKS

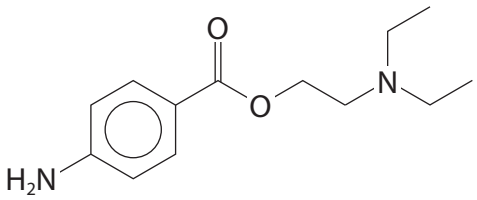
SECTION C

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

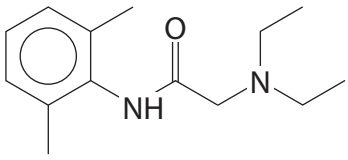
25 The synthetic drugs of the 'Caine' family are used as local anaesthetics.
Caine drugs prevent nerve activity by binding to sodium channel receptors in the lipid cell membranes of neurons.



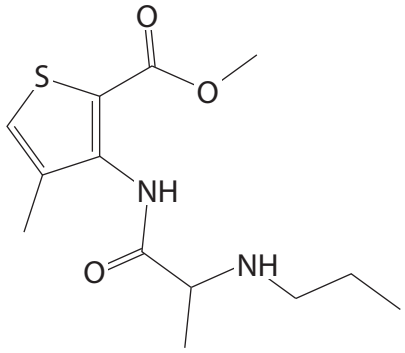
benzocaine



procaine



lidocaine



articaine

(a) Name the **three** functional groups present in benzocaine.

(2)

.....

.....

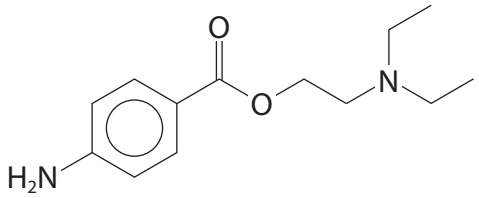
(b) Procaine can react with hydrochloric acid to form a monohydrochloride salt.

(i) Write an equation, using **molecular** formulae, for this reaction.
State symbols are not required.

(2)

(ii) Explain by considering **both** nitrogen atoms in procaine which nitrogen is more likely to be protonated in the reaction with hydrochloric acid.

(2)

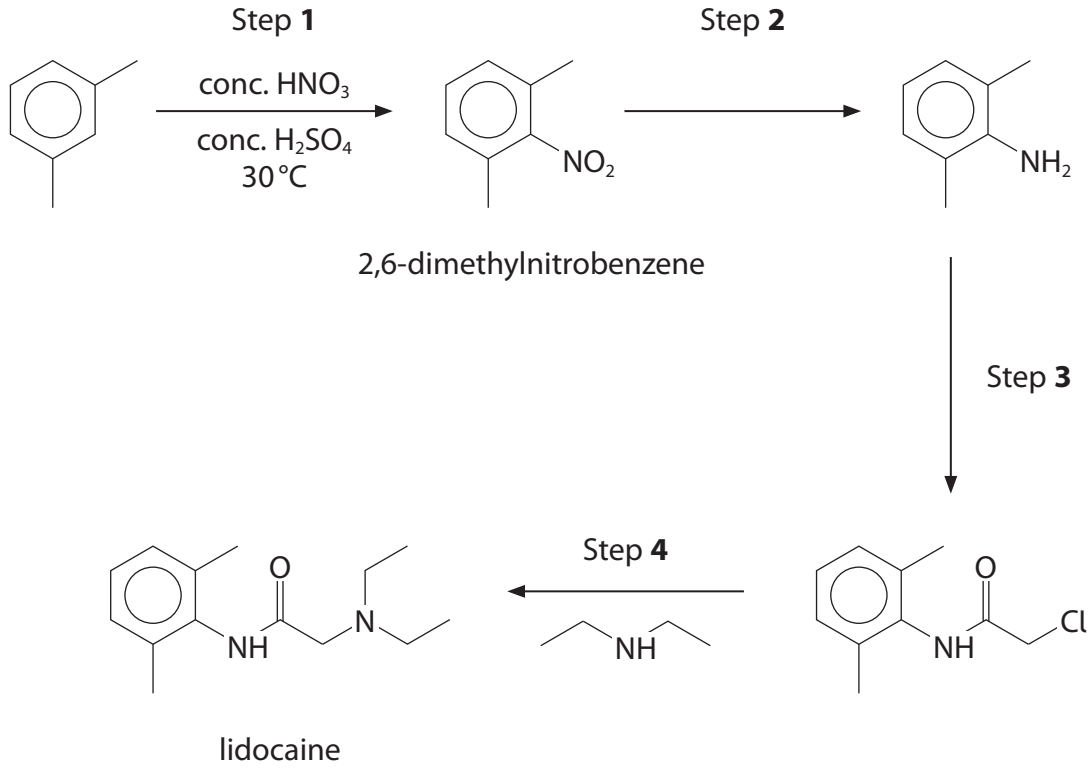


(c) When benzocaine and procaine are hydrolysed, one of the products formed is the same in both reactions.

Give the structure of this product.

(1)

(d) Lidocaine can be prepared in the synthesis shown.



(i) Give the mechanism for Step **1**.

Include an equation for the formation of the electrophile.

(4)

(ii) A low yield of 2,6-dimethylnitrobenzene is obtained in Step **1** due to the formation of additional organic products.

Give possible structures for **two** additional organic products.

(2)

(iii) Give the reagents for Step **2**.

(1)

.....

.....

(iv) Deduce the **skeletal** formula of the reagent for Step **3**.

(1)

(v) State the type and mechanism of reaction occurring in Step **4**.

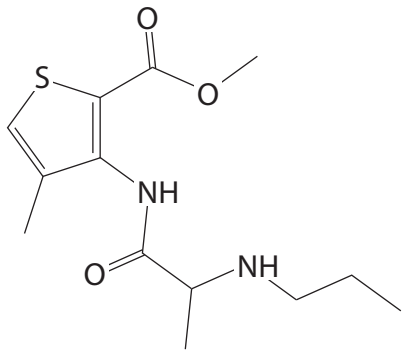
(1)

.....

(e) Articaine is a chiral molecule.

Indicate any chiral centres on the structure of articaine.

(1)



articaine

(f) Articaine is metabolised in the body with a half-life of 20 minutes.

A patient is given a dose of 100 mg of articaine.

Calculate the mass of articaine **in micrograms**, μg, remaining in the body after **4 hours**.

[1 μg = 10^{-3} mg]

(3)

(Total for Question 25 = 20 marks)

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