Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Friday 17 January 2025

Afternoon (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 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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H:1/1/1/1/

P 7 8 4 5 9 A 0 1 3 2

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 Which species **cannot** act as a ligand in the formation of a complex ion?

☒ **A** C_2H_6

☒ **B** CO

☒ **C** OH^-

☒ **D** $C_4H_9NH_2$

(Total for Question 1 = 1 mark)

2 An aqueous solution of a transition metal ion absorbs frequencies of light corresponding to green, yellow and red.

Which ion is likely to be in the solution?

☒ **A** Mn^{2+}

☒ **B** Co^{2+}

☒ **C** Ni^{2+}

☒ **D** Cu^{2+}

(Total for Question 2 = 1 mark)

3 The first five ionisation energies of four elements are shown.

Which are the ionisation energies of a transition metal?

☒ **A** 419 3051 4412 5877 7975

☒ **B** 578 1817 2745 11578 14831

☒ **C** 738 1451 7733 10541 13629

☒ **D** 758 1646 3232 4950 7671

(Total for Question 3 = 1 mark)

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

4 What is the colour of the VO^{2+} ion in aqueous solution?

- ☒ **A** blue
- ☒ **B** green
- ☒ **C** violet
- ☒ **D** yellow

(Total for Question 4 = 1 mark)

5 Which statement about a catalytic converter used to reduce toxic emissions from internal combustion engines is **not** true?

- ☒ **A** the catalyst contains platinum
- ☒ **B** CO and NO are absorbed by the catalyst
- ☒ **C** after the reaction, desorption of CO_2 and N_2 takes place
- ☒ **D** it is a heterogeneous catalytic reaction

(Total for Question 5 = 1 mark)

6 Which of these pairs of elements are both transition metals?

- ☒ **A** gold and scandium
- ☒ **B** gold and titanium
- ☒ **C** scandium and zinc
- ☒ **D** titanium and zinc

(Total for Question 6 = 1 mark)

7 What are the shapes of the complexes $[CuCl_4]^{2-}$ and $Pt(NH_3)_2Cl_2$?

	$[CuCl_4]^{2-}$	$Pt(NH_3)_2Cl_2$
☒ **A**	square planar	square planar
☒ **B**	square planar	tetrahedral
☒ **C**	tetrahedral	square planar
☒ **D**	tetrahedral	tetrahedral

(Total for Question 7 = 1 mark)

8 Which is correct about standard electrode potentials?

☒ **A** $E^{\ominus}_{cell}$ is proportional to $\ln K$ and $\ln \Delta S_{total}$

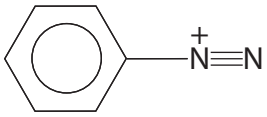
☒ **B** $E^{\ominus}_{cell}$ is proportional to $\ln K$ and ΔS_{total}

☒ **C** $\ln E^{\ominus}_{cell}$ is proportional to K and ΔS_{total}

☒ **D** $E^{\ominus}_{cell}$ is proportional to $\ln K$ and $\Delta S_{surroundings}$

(Total for Question 8 = 1 mark)

9 (a) Which reagents are mixed with hydrochloric acid to produce the benzenediazonium ion?



benzenediazonium ion

(1)

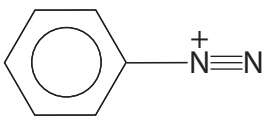
☒ **A** $C_6H_5NH_2$ and $NaNO_2$

☒ **B** $C_6H_5NO_2$ and $NaNO_2$

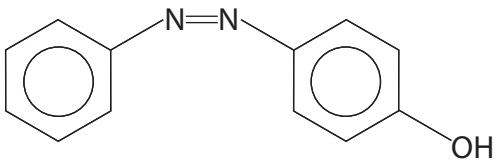
☒ **C** $C_6H_5NO_2$ and $NaNO_3$

☒ **D** $C_6H_5NH_2$ and $NaNO_3$

(b) Which reagents and conditions are used to prepare the yellow dye 4-phenyldiazenylphenol from the benzenediazonium ion?



benzenediazonium ion



4-phenyldiazenylphenol

(1)

☒ **A** phenol dissolved in an acid solution at 25 °C

☒ **B** phenol dissolved in an alkaline solution at 25 °C

☒ **C** phenol dissolved in an acid solution at 5 °C

☒ **D** phenol dissolved in an alkaline solution at 5 °C

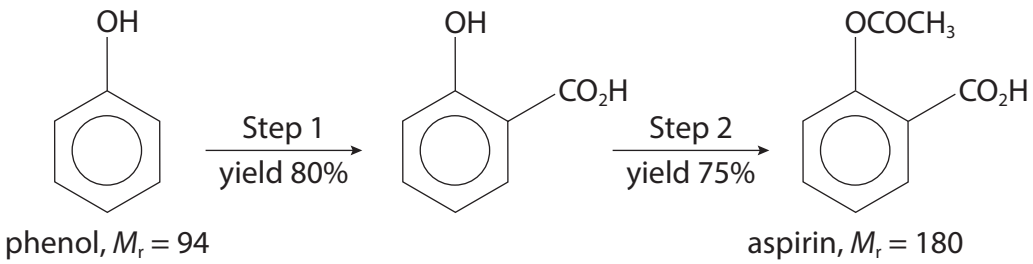
(Total for Question 9 = 2 marks)

10 Which sequence describes recrystallisation?

- ☒ **A** dissolve in the minimum volume of cold solvent, filter to remove the insoluble impurities, then add hot solvent and filter to remove the soluble impurities
- ☒ **B** dissolve in the minimum volume of hot solvent, filter to remove the soluble impurities, wash with cold solvent to remove the insoluble impurities
- ☒ **C** dissolve in the minimum volume of hot solvent, filter to remove the insoluble impurities, then cool and filter to remove the soluble impurities
- ☒ **D** dissolve in the minimum volume of hot solvent, filter to remove the soluble impurities, then cool and filter to remove the insoluble impurities

(Total for Question 10 = 1 mark)

11 A synthesis of aspirin from phenol is shown.



phenol, $M_r = 94$ aspirin, $M_r = 180$

What mass of aspirin is formed from 23.5 g of phenol?

- ☒ **A** 14.1 g
- ☒ **B** 27.0 g
- ☒ **C** 33.8 g
- ☒ **D** 36.0 g

(Total for Question 11 = 1 mark)

12 An 8.4 g sample of a hydrocarbon formed 26.4 g of carbon dioxide on complete combustion. What is the molecular formula of this compound?

- ☒ **A** CH_2
- ☒ **B** C_6H_6
- ☒ **C** C_2H_6
- ☒ **D** C_6H_{12}

(Total for Question 12 = 1 mark)

13 What are the volumes of oxygen required **and** carbon dioxide produced, at room temperature and pressure (r.t.p.), on complete combustion of 5.8 g of butane, C_4H_{10}?

[Molar volume of a gas at r.t.p. = 24.0 $dm^3 mol^{-1}$ M_r C_4H_{10} = 58.0]

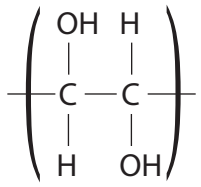
		volume of oxygen / dm^3	volume of carbon dioxide / dm^3
☒	**A**	15.6	9.6
☒	**B**	12.0	9.6
☒	**C**	21.6	2.4
☒	**D**	15.6	12.0

(Total for Question 13 = 1 mark)

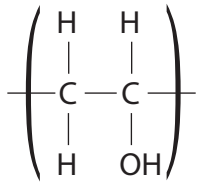
Use this space for any rough working. Anything you write in this space will gain no credit.

14 What is the repeat unit of the water-soluble polymer poly(ethenol)?

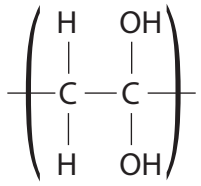
☒ **A**



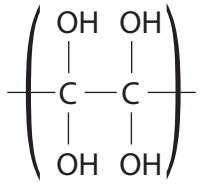
☒ **B**



☒ **C**

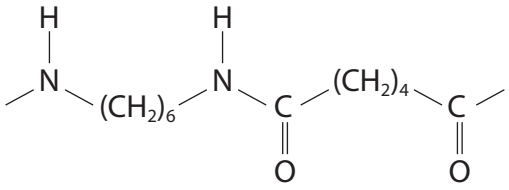


☒ **D**



(Total for Question 14 = 1 mark)

15 A repeat unit for a polyamide is shown.



Which pair of monomers makes this polymer?

☒ **A** $H_2N(CH_2)_6NH_2$ and $HOOC(CH_2)_4COOH$

☒ **B** $NC(CH_2)_6CN$ and $HOOC(CH_2)_4COOH$

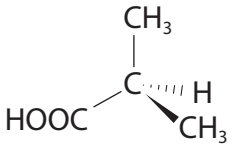
☒ **C** $H_2N(CH_2)_4NH_2$ and $HOOC(CH_2)_6COOH$

☒ **D** $H_2N(CH_2)_6NH_2$ and $HO(CH_2)_6OH$

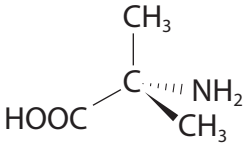
(Total for Question 15 = 1 mark)

16 Four compounds (W, X, Y and Z) are shown.

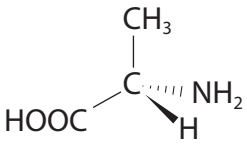
W



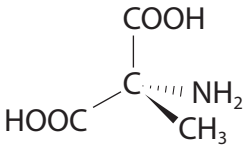
X



Y



Z



(a) Which compound is an optically active amino acid?

(1)

☒ **A** compound W

☒ **B** compound X

☒ **C** compound Y

☒ **D** compound Z

(b) Which compound does **not** have the same number of peaks in the low-resolution proton NMR spectrum **and** in the ^{13}C NMR spectrum?

(1)

☒ **A** compound W

☒ **B** compound X

☒ **C** compound Y

☒ **D** compound Z

(Total for Question 16 = 2 marks)

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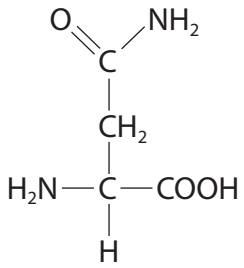
17 Asparagine is an amino acid.

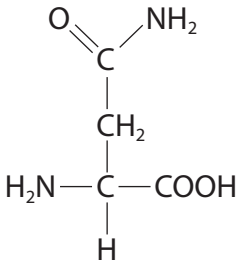


asparagine

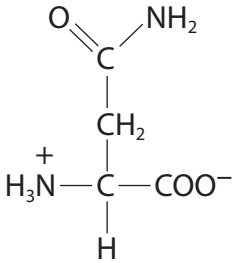
(a) What will be the structure of asparagine in an aqueous solution at pH 2?

(1)

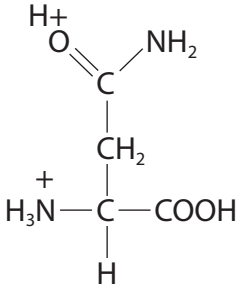
☒ **A**



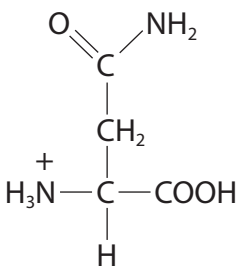
☒ **B**



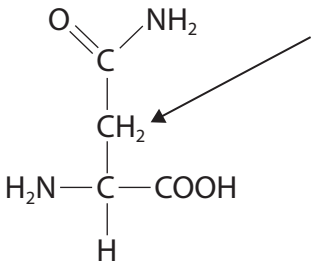
☒ **C**



☒ **D**



(b) In a high-resolution proton NMR spectrum of asparagine, what would be the splitting pattern for the protons indicated by the arrow?



(1)

- ☒ **A** singlet
- ☒ **B** doublet
- ☒ **C** triplet
- ☒ **D** quartet

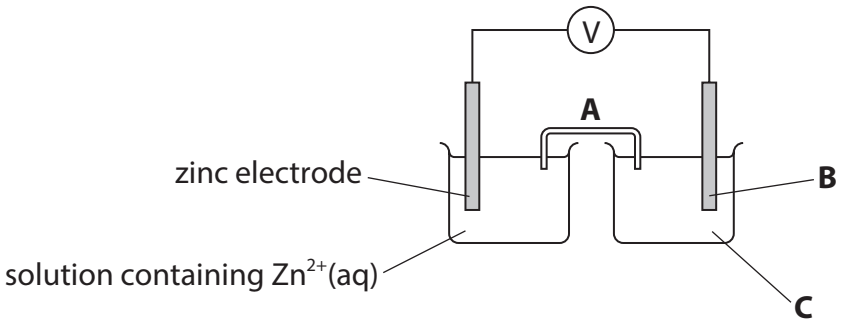
(Total for Question 17 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

18 The standard emf, $E^{\ominus}_{cell}$, of the cell shown was measured.



Electrode system	Standard electrode potential $E^{\ominus}$/V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77

(a) (i) Identify, by name or formula, the substances needed in the salt bridge and the right-hand half-cell. Include concentrations where appropriate.

(4)

A Salt bridge containing a solution of the compound

.....

.....

B Electrode made of

.....

C Solution containing the compounds

.....

.....

.....

(ii) State why a salt bridge is used rather than a wire.

(1)

.....

.....

(b) Write an equation for the reaction that would take place if current was allowed to flow through the circuit. State symbols are not required.

(2)

(c) Under standard conditions, the $E^{\ominus}_{cell}$ for this reaction is +1.53 V.

State what would happen to this value, if anything, when the Zn^{2+} solution in the half-cell is diluted. Justify your answer.

(2)

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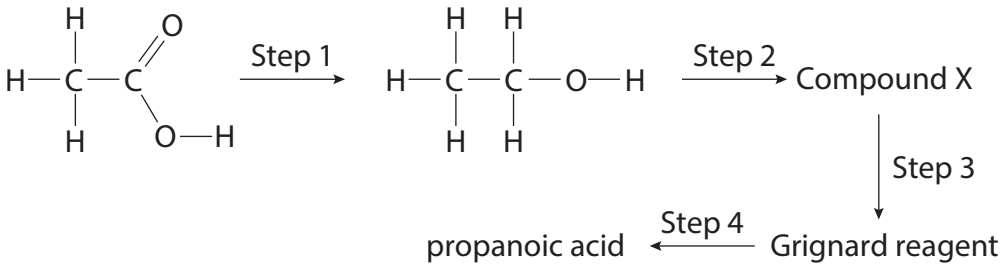
(Total for Question 18 = 9 marks)

19 Grignard reagents are used to increase the length of the carbon chain in organic molecules.

An outline synthesis of propanoic acid from ethanoic acid is shown.



Complete the table.

Step **1** reagent(s) and conditions	
Step **2** reagent(s)	
Name or formula of compound X	
Step **3** reagent(s) and conditions	
Formula of the Grignard reagent	
Step **4** reagent(s)	

(Total for Question 19 = 6 marks)

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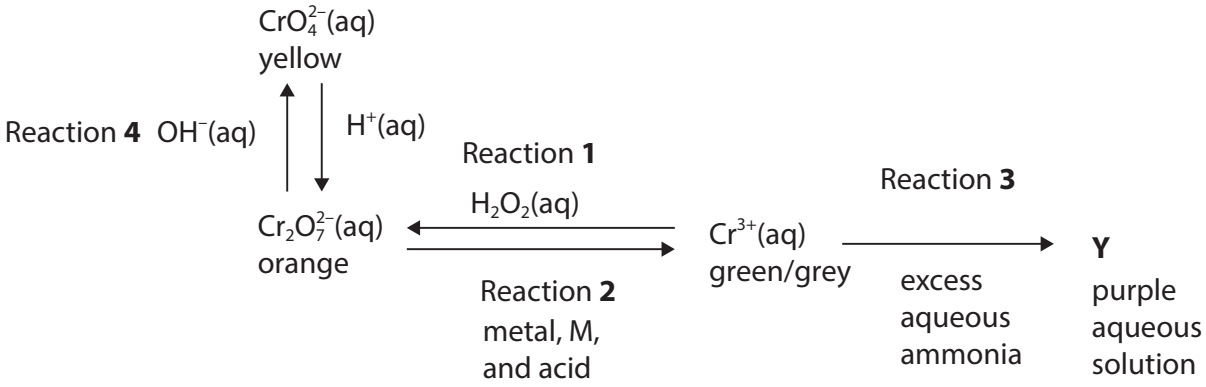
20 This question is about some chromium compounds.

(a) Some reactions of chromium compounds are shown.



(i) Write the equation for Reaction **1**. Use the half-equations from page 10 of your Data Booklet. State symbols are **not** required.

(2)

(ii) In Reaction **2**, $Cr_2O_7^{2-}$ reacts with a metal, M, in acid conditions forming Cr^{3+} and M^{2+}.

Identify a possible metal, M, calculating $E^{\ominus}_{cell}$ for its reaction with $Cr_2O_7^{2-}$.

Use information from page 10 of your Data Booklet.

(2)

(iii) Give the formula of the species responsible for the purple colour formed in Reaction **3**, naming the type of reaction that occurs.

(2)

(iv) State whether or not the reaction in Reaction **4** is a redox reaction.
Justify your answer using oxidation numbers.

(2)

.....

.....

.....

(b) A double salt of chromium contains Cr^{3+}, K^+ and SO_4^{2-} ions.

(i) Deduce the simplest formula of this double salt.

(1)

.....

(ii) The double salt also exists as hydrated crystals.
When a sample of the hydrated double salt is heated until all the water of crystallisation is removed, 56.74 % of the original mass of solid remains.

Calculate the number of moles of water of crystallisation in one mole of the hydrated double salt.

(4)

(c) We require small amounts of chromium(III) ions, Cr^{3+}, in our diet as they are important in the breakdown of fats, and many other body processes. However, too high a concentration of Cr^{3+} is toxic.

Blood should not contain more than 4 parts per billion by mass of Cr^{3+}.

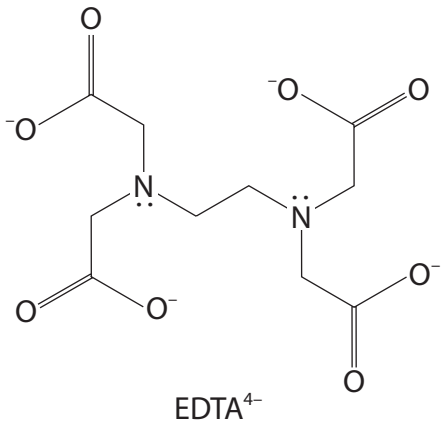
The concentration of Cr^{3+} in a blood sample was 1.345×10^{-7} mol dm^{-3}.

(i) Show, by calculation, that the Cr^{3+} level in this blood sample exceeds the safe limit.

[1 billion = 1×10^{9} Assume the density of blood is 1.0 g cm^{-3}]

(2)

(ii) $EDTA^{4-}$ has been considered as a potential treatment for Cr^{3+} poisoning.



$EDTA^{4-}$

Suggest how $EDTA^{4-}$ would act to treat Cr^{3+} poisoning, giving a reason why $EDTA^{4-}$ would be preferred to other reagents such as 1,2-diaminoethane, $NH_2CH_2CH_2NH_2$.

(2)

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(Total for Question 20 = 17 marks)

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21 This question is about iron(II) sulfate, $FeSO_4$.

(a) (i) The electronic configuration for Fe is shown.

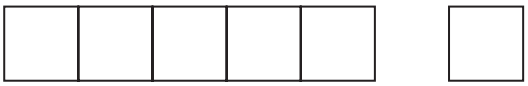
(1)

Fe [Ar]

3d 4s

Complete the electronic configuration for the Fe^{2+} ion in iron(II) sulfate.

Fe^{2+} [Ar]



3d 4s

(ii) An aqueous solution of iron(II) sulfate is pale green in colour.
When left exposed to the air the solution turns brown.

Explain why this colour change occurs. In your response refer to your answer from (a)(i).

(3)

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.....

.....

(b) Many moss killers contain iron(II) sulfate, $FeSO_4$, as the active compound. Potassium manganate(VII) can be used to determine the amount of iron(II) sulfate present.

In an experiment, 6.42 g of moss killer was transferred to a volumetric flask and made up to 250 cm^3 with distilled water. A 25.0 cm^3 portion of this solution was acidified and titrated with 0.00740 mol dm^{-3} potassium manganate(VII) solution.

The equation for the titration is shown.

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

The mean titre was 17.70 cm^3.

Calculate the percentage, by mass, of iron(II) sulfate in the moss killer.
Give your answer to an appropriate number of significant figures.

[Molar mass $FeSO_4$ = 151.9 g mol^{-1}]

(6)

(c) Suggest why iron(II) sulfate is acidic when dissolved in water.

(2)

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(Total for Question 21 = 12 marks)

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***22** Compare and contrast the bromination of benzene and the bromination of phenol.

Include equations in your answer.

Detailed mechanisms are **not** required.

(6)

(Total for Question 22 = 6 marks)

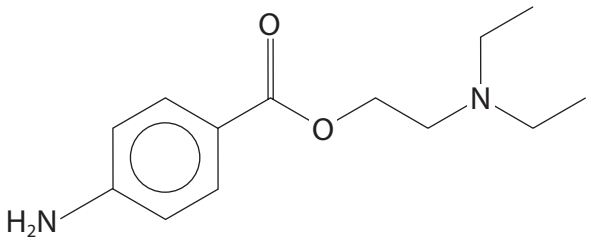
TOTAL FOR SECTION B = 50 MARKS

SECTION C

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

23 **Local anaesthetics in dentistry**

Procaine is a local anaesthetic that was commonly used until the end of the last century in dental procedures to numb the area around a tooth.

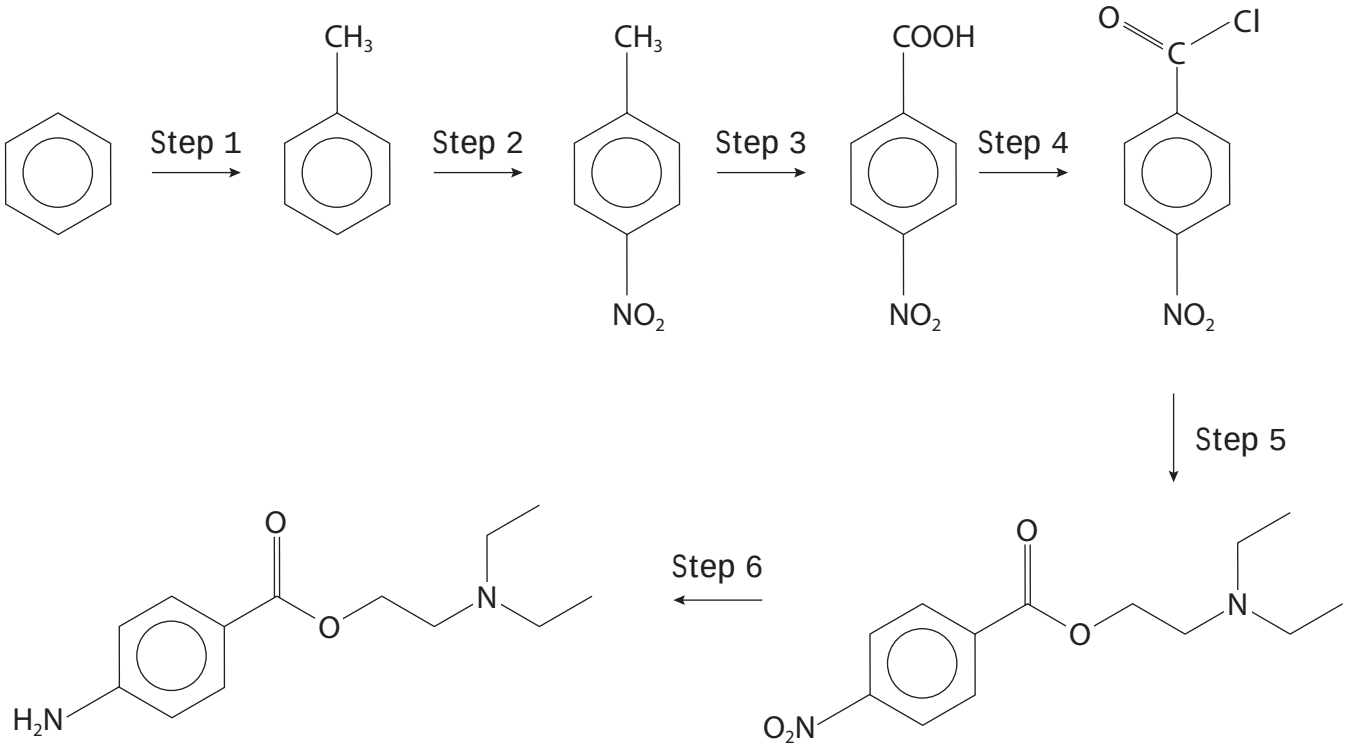


procaine

(a) Deduce the molecular formula of procaine.

(1)

(b) A possible reaction sequence to make procaine is shown.



(i) Identify, by name or formula, the two reagents needed for Step **1**.

(2)

.....

.....

.....

(ii) For Step **2**, draw the mechanism for this reaction, including the formation of a suitable electrophile and the regeneration of the catalyst.
Include curly arrows.

(5)

(iii) For Step **5**, name the type of reaction taking place and draw the skeletal formula of the reagent needed to carry out this reaction.

(2)

Type of reaction

.....

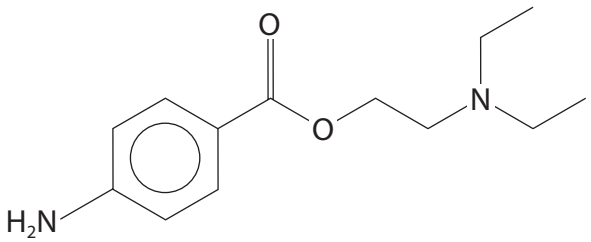
Skeletal formula of the reagent

(iv) Identify, by name or formula, the reagents required for Step **6**.

(1)

.....

(c) Procaine contains two nitrogen atoms, one of which is a stronger base than the other.



procaine

(i) Explain why the basicity of the nitrogen atoms in procaine is different.

(3)

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(ii) Procaine hydrochloride is made by reacting procaine with hydrogen chloride in a 1 : 1 ratio.

Draw the structure of procaine hydrochloride, showing how the hydrogen ion attaches to the molecule.

(1)

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(iii) Explain why procaine hydrochloride is more soluble in aqueous solutions such as blood plasma than procaine.

(2)

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(d) Nowadays, procaine has been replaced by lidocaine, a related compound, as a local anaesthetic in dentistry.

Lidocaine is supplied in 2.2 cm^3 cartridges that contain 44 mg of lidocaine. A typical adult dose is 1.5 cm^3.

Calculate the number of molecules of lidocaine present in a 1.5 cm^3 dose.

[Molar mass lidocaine = 234 g mol^{-1}]

(3)

(Total for Question 23 = 20 marks)

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

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
																	(18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)											(13)	(14)	(15)	(16)	(17)	
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	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(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							

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

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