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Candidate surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number | | | | | |

Candidate Number | | | | |

Tuesday 9 June 2020

Morning (Time: 1 hour 40 minutes) | Paper Reference **WCH05/01**

Chemistry
Advanced
Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Candidates must have: Scientific calculator
Data Booklet

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **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.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
  – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

Advice

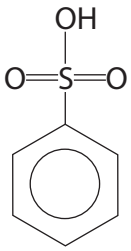
- Read each question carefully before you start to answer it.
- Show all your working in calculations and give units where appropriate.
- Check your answers if you have time at the end.

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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 A reaction of benzene produces benzenesulfonic acid:



This reaction is carried out using

☒ **A** concentrated nitric acid and concentrated sulfuric acid.

☒ **B** concentrated sulfuric acid.

☒ **C** fuming sulfuric acid.

☒ **D** sulfur dioxide and steam.

(Total for Question 1 = 1 mark)

2 It may be deduced that benzene is unsaturated because it

☒ **A** decolourises bromine water.

☒ **B** turns acidified potassium dichromate(VI) green on heating.

☒ **C** burns with a smoky flame.

☒ **D** forms separate layers when added to water.

(Total for Question 2 = 1 mark)

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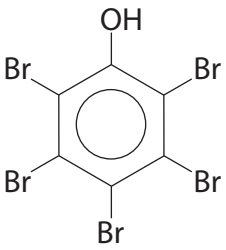
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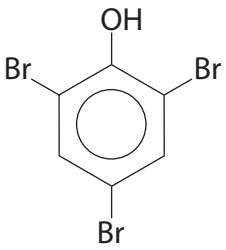
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3 Which is/are the organic product(s) of the reaction of phenol with excess aqueous bromine?

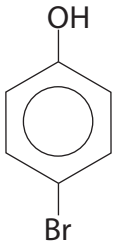
☒ **A**

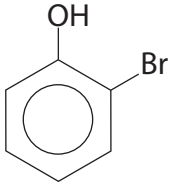


☒ **B**

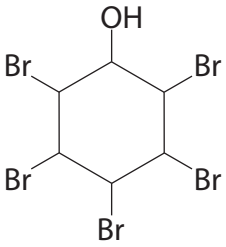


☒ **C**

mixture of 

and 

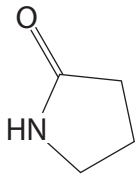
☒ **D**



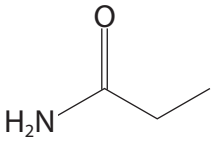
(Total for Question 3 = 1 mark)

4 Which molecule has an amine functional group?

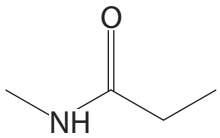
☒ **A**



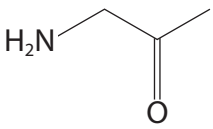
☒ **B**



☒ **C**



☒ **D**

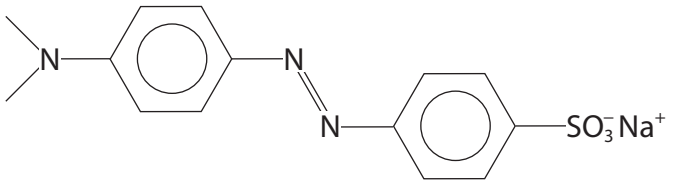


(Total for Question 4 = 1 mark)

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5 Methyl orange is an indicator with the structure



(a) Methyl orange is an azo dye. The benzenediazonium intermediate can be made using

(1)

☒ **A** HNO_2

☒ **B** HNO_3

☒ **C** H_2SO_4 and HNO_3

☒ **D** HCl only

(b) The reaction conditions for the formation of methyl orange from the benzenediazonium intermediate are

(1)

☒ **A** reflux at 50–55 °C.

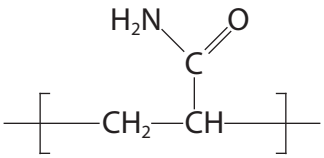
☒ **B** heat with $AlCl_3$.

☒ **C** $LiAlH_4$ in dry ether.

☒ **D** ice-cold alkaline solution.

(Total for Question 5 = 2 marks)

6 An example of an addition polymer is



Which of these is the monomer of this polymer?

☒ **A** $CH_3CH_2CONH_2$

☒ **B** $CH_2CHCONH_2$

☒ **C** $H_2NCHCHCOOH$

☒ **D** $CH_3CH(OH)CONH_2$

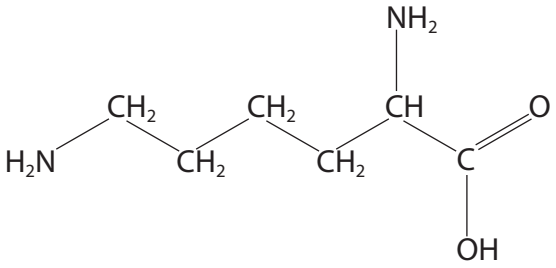
(Total for Question 6 = 1 mark)

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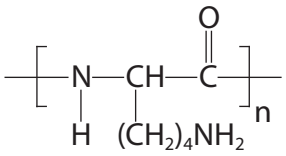
7 The amino acid lysine has the structure



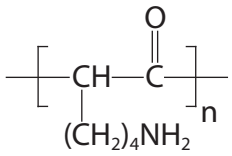
(a) Which of these could be a repeat unit for poly(lysine)?

(1)

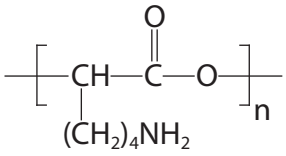
☒ **A**



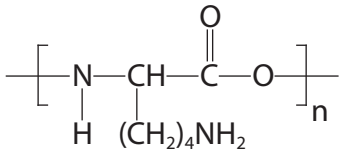
☒ **B**



☒ **C**



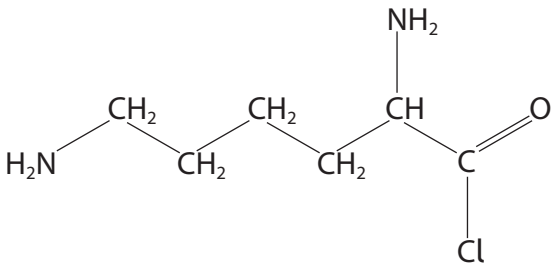
☒ **D**



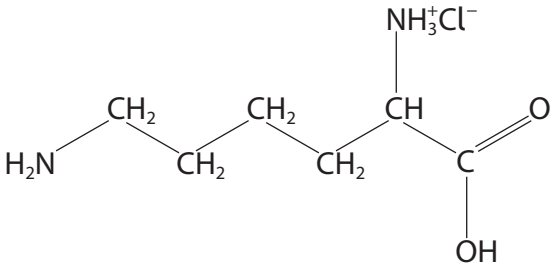
(b) The reaction of lysine with **excess** hydrochloric acid produces

(1)

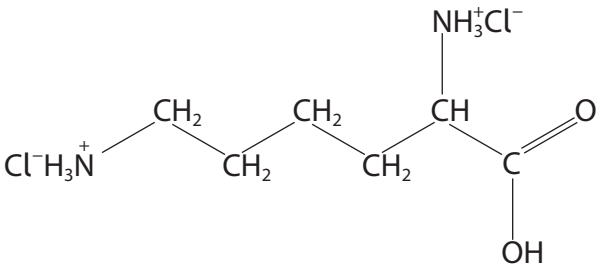
☒ **A**



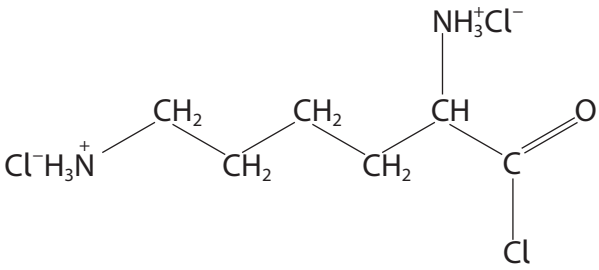
☒ **B**



☒ **C**



☒ **D**



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(c) The presence of amino acids such as lysine can be detected by the use of

(1)

☒ **A** 2,4-dinitrophenylhydrazine (Brady's reagent).

☒ **B** iodine.

☒ **C** ninhydrin.

☒ **D** Tollens' reagent.

(d) Lysine is a crystalline solid with a high melting temperature.

The best explanation is that

(1)

☒ **A** each lysine molecule has strong London forces due to the high number of electrons.

☒ **B** each lysine molecule can form hydrogen bonds at both ends.

☒ **C** proton transfer within the molecules results in ionic bonding.

☒ **D** the molecular shape allows the molecules to pack together closely.

(Total for Question 7 = 4 marks)

8 The reaction of aluminium with oxygen has $E^{\ominus}_{cell} = +2.17V$.

Aluminium is corrosion-resistant in air because

☒ **A** aluminium does not react with oxygen.

☒ **B** aluminium forms a stable oxide coating.

☒ **C** the reaction is not carried out under standard conditions.

☒ **D** the reaction is not thermodynamically feasible.

(Total for Question 8 = 1 mark)

9 A disadvantage of the use of methanol in a fuel cell is that methanol is

☒ **A** difficult to store.

☒ **B** difficult to transport.

☒ **C** flammable.

☒ **D** made from fossil fuels.

(Total for Question 9 = 1 mark)

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10 The colour of the complex $[CrCl_4]^-$ in aqueous solution is due to the

- ☒ **A** movement of electrons to a higher quantum shell.
- ☒ **B** return of excited electrons to the ground state.
- ☒ **C** splitting of a d orbital.
- ☒ **D** promotion of electrons between d orbitals.

(Total for Question 10 = 1 mark)

11 The reaction shown is between aqueous chromium(III) ions and excess concentrated hydrochloric acid.

$$[Cr(H_2O)_6]^{3+} + 4Cl^- \rightarrow [CrCl_4]^- + 6H_2O$$

(a) This reaction is an example of

(1)

- ☒ **A** amphoteric behaviour.
- ☒ **B** ligand exchange.
- ☒ **C** oxidation of the chromium ion.
- ☒ **D** reduction of the chromium ion.

(b) What are the coordination numbers of the chromium ion in each complex?

(1)

	$[Cr(H_2O)_6]^{3+}$	$[CrCl_4]^-$
☒ **A**	1	1
☒ **B**	+3	−1
☒ **C**	6	6
☒ **D**	6	4

(Total for Question 11 = 2 marks)

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12 The advantage of steam distillation over distillation is that

☒ **A** it is cheaper to use steam.

☒ **B** the neutrality of the steam does not affect organic molecules.

☒ **C** the process is gentler with temperature-sensitive substances.

☒ **D** a safety valve or outlet is not required from the condenser.

(Total for Question 12 = 1 mark)

13 Ammonia, butylamine and phenylamine all form alkaline aqueous solutions.

The order of **increasing** pH of equimolar solutions is

☒ **A** phenylamine < butylamine < ammonia

☒ **B** ammonia < butylamine < phenylamine

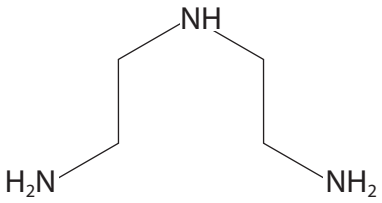
☒ **C** ammonia < phenylamine < butylamine

☒ **D** phenylamine < ammonia < butylamine

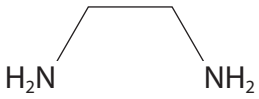
(Total for Question 13 = 1 mark)

14 Which of the following is **not** a bidentate ligand?

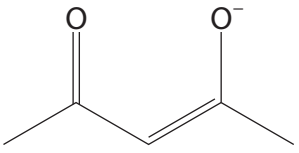
☒ **A**



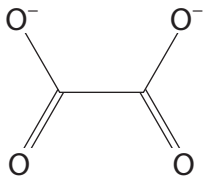
☒ **B**



☒ **C**



☒ **D**



(Total for Question 14 = 1 mark)

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15 The relationship of $E^{\ominus}_{cell}$ with ΔS and $E^{\ominus}_{cell}$ with $\ln K_c$ is

	ΔS	$\ln K_c$
☒ **A**	directly proportional	directly proportional
☒ **B**	directly proportional	indirectly proportional
☒ **C**	indirectly proportional	directly proportional
☒ **D**	indirectly proportional	indirectly proportional

(Total for Question 15 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

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

16 This is a question about gold, Au.

Some electrode potentials for gold are shown in the table. You will need these in addition to the values in the Data Booklet.

Right-hand electrode system	$E^{\ominus}$/ V
$Au^{3+}(aq), Au^{+}(aq) \mid Pt$	+1.29
$Au^{3+}(aq) \mid Au(s)$	+1.41
$Au^{+}(aq) \mid Au(s)$	+1.69

(a) An electrochemical cell is set up by connecting two half-cells, with electrodes of gold and silver dipping into separate solutions of gold(III) ions and silver(I) ions. Both solutions have a concentration of 1 mol dm^{-3}.

(i) Draw a labelled diagram of the apparatus to measure $E^{\ominus}_{cell}$ for this electrochemical cell.

(3)

(ii) Write the equation for the cell reaction, including state symbols, and calculate $E^{\ominus}_{cell}$.

(2)

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(iii) Explain, using the electrode potential data in the table, why aqueous solutions of gold(I) ions are unstable, giving an equation for the reaction that occurs.

State symbols are not required.

(2)

.....

.....

.....

.....

(b) Solutions containing gold(I) ions are stabilised by the addition of cyanide ions. The reaction is

$$Au^{+}(aq) + 2CN^{-}(aq) \rightarrow [Au(CN)_2]^{-}(aq)$$

(i) Suggest the shape of the $[Au(CN)_2]^{-}$ ion.

(1)

.....

(ii) During the production of gold from its ore, zinc is added to a solution containing $[Au(CN)_2]^{-}$ ions. The reaction is

$$2[Au(CN)_2]^{-}(aq) + Zn(s) \rightarrow 2Au(s) + [Zn(CN)_4]^{2-}(aq)$$

Explain which species is the reducing agent in this reaction, illustrating your answer with a half-equation.

(2)

.....

.....

.....

(Total for Question 16 = 10 marks)

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17 Chromium is a transition metal with many of the typical properties of these elements.

(a) State the meaning of the term 'transition metal'.

(1)

(b) Chromium and copper have the same outermost electronic configuration.

Give this outermost electronic configuration.

(1)

(c) Use your knowledge of the oxidation states of chromium to predict the formulae of **two** chromium oxides.

(1)

*(d) Green precipitates can be formed by the addition of a small volume of sodium hydroxide solution to separate aqueous solutions of Cr^{3+} ions, Fe^{2+} ions and Ni^{2+} ions.

Explain how separate samples of these precipitates can be distinguished.

(3)

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(e) On addition of excess ammonia, chromium(III) ions form hexaamminechromium(III), $[Cr(NH_3)_6]^{3+}$.

(i) Draw a diagram to show the three-dimensional shape of this complex ion.

(2)

(ii) State the H—N—H bond angle in this complex ion.
Justify your answer.

(2)

(iii) When EDTA is added to an aqueous solution of the $[Cr(NH_3)_6]^{3+}$ complex, the formation of the EDTA complex is favoured.

Explain why this is so.

(2)

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(f) Sodium chromate(VI), Na_2CrO_4, often contains impurities.

A procedure to determine the percentage purity by mass of a sample of sodium chromate(VI) involves:

- conversion of chromate(VI) ions into dichromate(VI) ions in acidic conditions
- use of the dichromate(VI) ions in acidic solution as an oxidising agent to convert Fe^{2+} to Fe^{3+}

Procedure

Step **1** 1.59 g of the sodium chromate(VI) sample is weighed out.

Step **2** The sample is transferred to a 250.0 cm^3 volumetric flask and 100 cm^3 of dilute sulfuric acid is added. The dichromate(VI) solution formed is made up to the mark with deionised water and thoroughly mixed.

Step **3** A burette is filled with the dichromate(VI) solution.

Step **4** 25.0 cm^3 of a 0.0492 mol dm^{-3} solution of ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2$, is pipetted into a conical flask.

Step **5** Sulfuric acid and phosphoric acid are added to the conical flask followed by a few drops of a diphenylamine indicator.

Step **6** The dichromate(VI) solution is added from the burette into the conical flask with swirling until an intense blue-violet colour forms.

Step **7** The titration was repeated until concordant results are obtained.

(i) Write a balanced ionic equation for the conversion of the chromate(VI) ions into dichromate(VI) ions in acidic solution to show the 2:1 molar ratio. State symbols are not required.

(1)

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(ii) Calculate the percentage purity by mass of the sodium chromate(VI) sample if the mean titre is 10.80 cm^3.
The reaction between the dichromate(VI) ions and the iron(II) ions is

$$Cr_2O_7^{2-} + 6Fe^{2+} + 14H^+ \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$$

(6)

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(g) There are a number of different industrial catalysts which contain chromium. One of these is copper(II) chromite(III), $Cu_2Cr_2O_5$ which is a solid used in organic synthetic pathways.

Suggest how a **heterogenous** catalyst, such as copper(II) chromite(III), speeds up the rate of a chemical reaction.

(3)

(Total for Question 17 = 22 marks)

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18 This is a question about an unknown organic compound, **X**.
X is an unbranched cyclic hydrocarbon.

The complete combustion of a 4.10 g sample of **X** formed 7.20 dm^3 of carbon dioxide and 4.50 g of water at room temperature and pressure.

(a) Use the combustion data to show that the molecular formula of **X** could be C_6H_{10}.

(3)

(b) The organic compound **Y** is formed when **X** reacts with excess liquid bromine.
The molecular formula of **Y** is $C_6H_{10}Br_2$.

Write the **displayed** formulae of **X** and **Y**.

(2)

(c) When **X** reacts with bromine **water**, a different organic compound **Z** is formed which has optical isomers.

(i) Draw the **skeletal** formula of **Z**.

(1)

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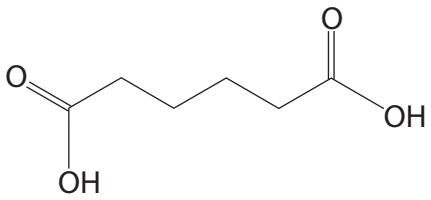
(ii) Describe how the presence of a single optical isomer could be detected, including the expected result.

(2)

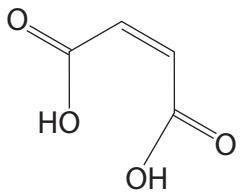
(d) Give the wavenumber ranges of **two** absorptions that you would expect in the infrared spectrum of **X**, indicating the bonds responsible.

(2)

(e) **X** is used to make a number of intermediates in industrial synthetic processes. Examples of such intermediates are adipic acid and maleic acid.



adipic acid



maleic acid

(i) State the systematic name of adipic acid.

(1)

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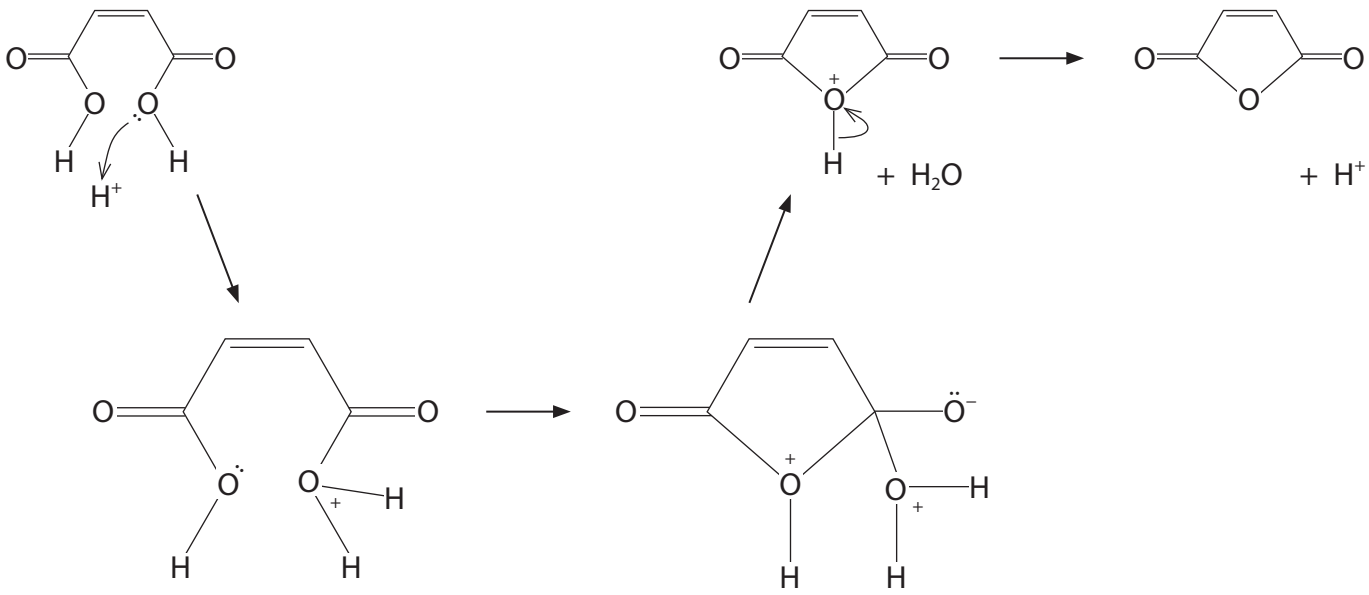
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(ii) Write an equation for the formation of a nylon polymer using adipic acid and an amine of your choice.

(3)

(iii) Maleic acid can undergo an elimination reaction, losing a water molecule.
A mechanism has been partly drawn for this reaction but **four** curly arrows are missing.
Complete the mechanism by adding the curly arrows.

(2)



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(iv) Draw the geometric isomer of maleic acid and suggest why this isomer is much less likely to undergo dehydration.

(2)

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(Total for Question 18 = 18 marks)

TOTAL FOR SECTION B = 50 MARKS

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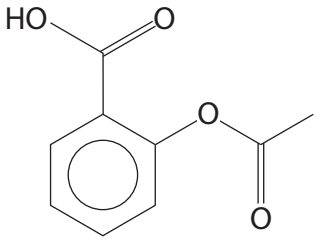
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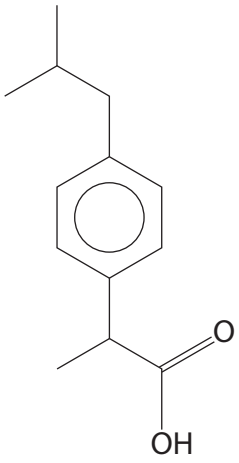
SECTION C

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

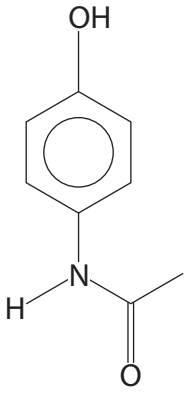
19 Aspirin, ibuprofen and paracetamol are common pain relievers that can be obtained without a doctor's prescription. Their structures are



aspirin



ibuprofen



paracetamol

These pharmaceutical drugs are included in the World Health Organization's model list of essential medicines. However, none of these drugs is without hazards. For example, possible side effects of taking aspirin include stomach bleeding and stomach ulcers.

These drugs may be taken in tablet or liquid form.

Adults can take ibuprofen and paracetamol at the same time if necessary. This is not recommended for children. The advice is to take ibuprofen with food or after having just eaten.

A compound related to aspirin is found in the bark of the willow tree. The health benefits of willow bark have been known for over 2000 years. Ibuprofen was discovered after many years of drug research into finding an anti-inflammatory drug to treat rheumatoid arthritis. Paracetamol was initially discovered in the 1880s, but it was not until the 1940s that it was further investigated by the pharmaceutical industry, which led to its worldwide use today.

(a) **Name** the functional group that is present in both aspirin and ibuprofen but not paracetamol.

(1)

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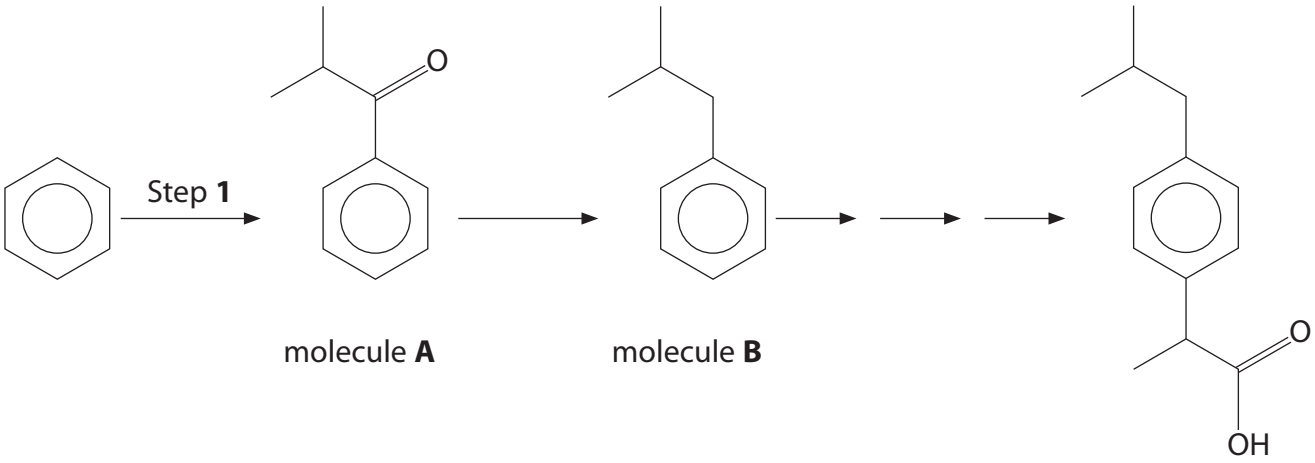
(b) Give the molecular formula of ibuprofen.

(1)

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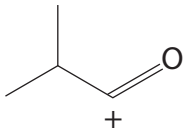
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(c) A simplified synthetic pathway for ibuprofen is shown.



(i) Use your knowledge of electrophilic substitution reactions to write the mechanism for the reaction of benzene in Step **1** with the electrophile shown.

(3)



electrophile

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(ii) Identify, by name or formula, an organic compound that could be used to form the electrophile given in (c)(i).

(1)

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(iii) Give a reason why lithium tetrahydridoaluminate(III) in dry ether cannot be used to convert molecule **A** into molecule **B**.

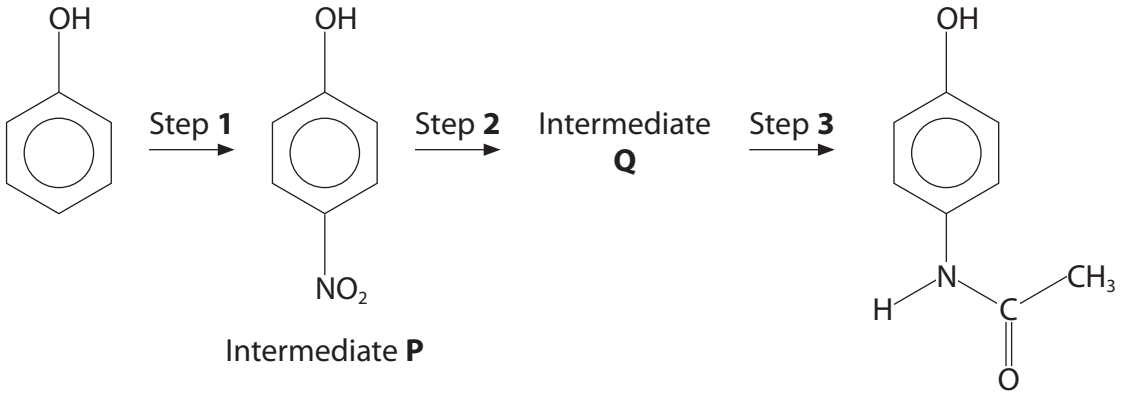
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(d) Paracetamol can be synthesised from phenol.
A summarised synthetic pathway is shown.



Intermediate **P**

*(i) Step **1** does **not** require a mixture of concentrated nitric acid and concentrated sulfuric acid, which is required for the nitration of benzene.

Explain why the nitration of phenol (Step **1**) occurs in much milder conditions than the nitration of benzene. State the reagents and conditions required.

(3)

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(ii) State the reagents and conditions required to convert intermediate **P** into paracetamol in Steps **2** and **3**. Identify intermediate **Q**.

(3)

(e) Aspirin is only slightly soluble in water.

(i) Calculate the **volume** of aspirin solution, of concentration 0.0161 mol dm^{-3}, required to give the same dose of aspirin as **two** 300 mg tablets of aspirin. Give your answer to three significant figures and include units.

(3)

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(ii) Give the **skeletal** formula of the sodium salt of aspirin.

(1)

(iii) Give a reason why the sodium salt of aspirin is used when the drug is required in liquid form.

(1)

(f) At times, a stereo-specific drug molecule needs to be synthesised.

Give **two** reasons why a single enantiomer may be required.

(2)

(Total for Question 19 = 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)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li ithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									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 odium 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 tassium 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 ubidium 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 aesium 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 ancium 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

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 mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

* Lanthanide series

* Actinide series

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