FOR OFFICIAL USE

National Qualifications 2017

Mark

X713/77/01

Chemistry
Section 1 — Answer Grid and Section 2

MONDAY, 8 MAY

9:00 AM – 11:30 AM

X7137701

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day | Month | Year

Scottish candidate number

You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.

Total marks — 100

SECTION 1 — 30 marks

Attempt ALL questions.

Instructions for the completion of Section 1 are given on *Page 02*.

SECTION 2 — 70 marks

Attempt ALL questions.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

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X7137701 01

SECTION 1 — 30 marks

The questions for Section 1 are contained in the question paper X713/77/02.

Read these and record your answers on the answer grid on *Page 03* opposite.

Use **blue** or **black** ink. Do NOT use gel pens or pencil.

1. The answer to each question is **either** A, B, C or D. Decide what your answer is, then fill in the appropriate bubble (see sample question below).

2. There is **only one correct** answer to each question.

3. Any rough working should be done on the additional space for answers and rough work at the end of this booklet.

Sample Question

To show that the ink in a ball-pen consists of a mixture of dyes, the method of separation would be:

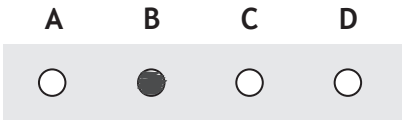
A fractional distillation

B chromatography

C fractional crystallisation

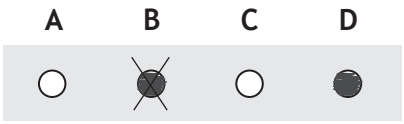
D filtration.

The correct answer is **B** — chromatography. The answer **B** bubble has been clearly filled in (see below).

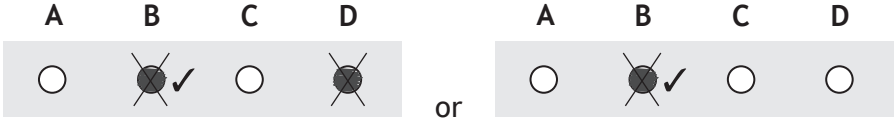


Changing an answer

If you decide to change your answer, cancel your first answer by putting a cross through it (see below) and fill in the answer you want. The answer below has been changed to **D**.



If you then decide to change back to an answer you have already scored out, put a tick (✓) to the **right** of the answer you want, as shown below:



SECTION 1 — Answer Grid

OBJ30AD1

	A	B	C	D		A	B	C	D
1	○	○	○	○	16	○	○	○	○
2	○	○	○	○	17	○	○	○	○
3	○	○	○	○	18	○	○	○	○
4	○	○	○	○	19	○	○	○	○
5	○	○	○	○	20	○	○	○	○
6	○	○	○	○	21	○	○	○	○
7	○	○	○	○	22	○	○	○	○
8	○	○	○	○	23	○	○	○	○
9	○	○	○	○	24	○	○	○	○
10	○	○	○	○	25	○	○	○	○
11	○	○	○	○	26	○	○	○	○
12	○	○	○	○	27	○	○	○	○
13	○	○	○	○	28	○	○	○	○
14	○	○	○	○	29	○	○	○	○
15	○	○	○	○	30	○	○	○	○

X713770103

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X7137701044

SECTION 2 — 70 marks

Attempt ALL questions

1. Many of the paints used by artists contain cadmium compounds.

The presence of cadmium in a paint sample can be detected by atomic emission spectroscopy.

(a) (i) Explain how a line is produced in an emission spectrum. **2**

(ii) Explain why there is a series of lines at discrete wavelengths in the emission spectrum of cadmium. **1**

(b) The cadmium emission spectrum has a line at 644 nm.

Calculate the energy, in kJ mol^{-1}, associated with this wavelength. **2**

2. Phosphorus forms different compounds with chlorine.

(a) When heated, phosphorus pentachloride dissociates to form phosphorus trichloride and chlorine.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H = +124\ kJ\ mol^{-1}$$

In an experiment to determine the equilibrium constant, K, 0·100 mol of PCl_5 was placed in a sealed 1·00 litre flask and heated to 250 °C. At equilibrium 0·0420 mol of PCl_3 had been formed.

(i) Calculate the equilibrium constant, K, for the reaction at 250 °C. **3**

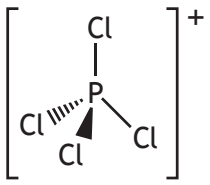
(ii) The temperature of the equilibrium mixture was increased to 400 °C.

Explain the effect of this change in temperature on the value of the equilibrium constant, K. **2**

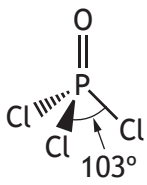
2. (continued)

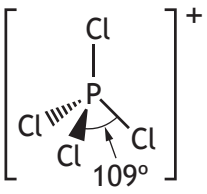
(b) In the solid state, phosphorus pentachloride is ionic and has the formula $[PCl_4]^+[PCl_6]^-$.

(i) The three-dimensional structure for the $[PCl_4]^+$ ion is shown. Complete the table for the $[PCl_6]^-$ ion. **1**

Phosphorus species	*Three-dimensional structure*
$[PCl_4]^+$	
$[PCl_6]^-$	

(ii) Phosphorus oxychloride, $POCl_3$, has a similar three-dimensional structure to the $[PCl_4]^+$ ion as shown.





Suggest a reason why the bond angle in the $POCl_3$ molecule is less than the bond angle in the $[PCl_4]^+$ ion. **1**

3. Zinc is often found in nature together with lead in sulfide ores. Different industrial processes can be used for the production of zinc metal. One of these is an electrolytic process and another is a thermal process.

(a) In the electrolytic process, zinc sulfide is converted into zinc oxide by roasting in a furnace at 1300 K.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

The data in the table refers to this reaction.

Substance	$\Delta H_f°$ (kJ mol^{-1})	$S°$ (J K^{-1} mol^{-1})
ZnS(s)	−206	58
O_2(g)	0	205
ZnO(s)	−350	44
SO_2(g)	−297	248

(i) For the conversion of zinc sulfide into zinc oxide, use the data in the table to calculate:

(A) $\Delta H°$, in kJ mol^{-1}; **1**

(B) $\Delta S°$, in J K^{-1} mol^{-1}. **1**

(ii) Calculate the theoretical temperature, in K, above which the reaction is no longer feasible. **2**

3. (continued)

(b) In the thermal process, a mixture of zinc oxide and lead oxide is reacted with carbon in a furnace at a temperature of 1200 K.

Data for the metals and metal oxides are shown in the table below.

Substance	*Density* ($g\ cm^{-3}$)	*Melting point* (K)	*Boiling point* (K)
Zn	7·1	693	1181
Pb	11·3	600	2024
ZnO	5·6	2248	2633
PbO	9·5	1161	1808

By considering all the information, suggest how a sample of zinc metal and a sample of lead metal could each be removed from the furnace. **2**

[Turn over

4. Transition metals, such as vanadium and copper, can have variable oxidation states and a wide range of uses.

(a) Vanadium dioxide, VO_2, can be used to coat glass.

(i) State the oxidation number of vanadium in VO_2. **1**

(ii) Using orbital box notation, write the electronic configuration, in terms of s, p and d orbitals, for the vanadium ion in VO_2. **1**

(b) Vanadium(III) ions can react with iron(III) ions in solution.

$$V^{3+}(aq) + Fe^{3+}(aq) \rightarrow V^{4+}(aq) + Fe^{2+}(aq)$$

(i) The reaction is first order with respect to both $V^{3+}(aq)$ and $Fe^{3+}(aq)$.
Write the rate equation for this reaction. **1**

4. (b) (continued)

(ii) In the presence of a $Cu^{2+}(aq)$ catalyst, the reaction mechanism is:

$$Cu^{2+}(aq) + V^{3+}(aq) \xrightarrow{\text{slow}} Cu^{+}(aq) + V^{4+}(aq)$$

$$Cu^{+}(aq) + Fe^{3+}(aq) \xrightarrow{\text{fast}} Cu^{2+}(aq) + Fe^{2+}(aq)$$

(A) State the order of the reaction with respect to $Fe^{3+}(aq)$ when a $Cu^{2+}(aq)$ catalyst is present.

Explain your answer. **2**

(B) Explain why $Cu^{2+}(aq)$ can be described as a homogeneous catalyst in this reaction. **1**

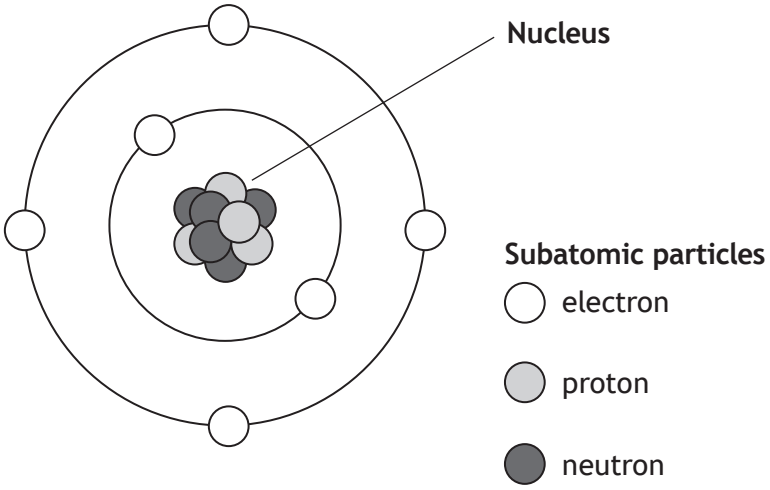
(c) In the Middle Ages, Damascus steel was used for making sword blades.

The steel from a sword blade of mass 1300 g was found to have a vanadium concentration of 71 ppm.

Calculate the total mass of vanadium present in the sword blade. **2**

[Turn over

5. A simple model of an atom is shown.



This simplistic model can be useful to help explain bonding but it is also misleading, as the structure of the atom and bonding are more complicated.

Using your knowledge of chemistry, discuss the strengths and weaknesses of this simple model compared to the concepts of atomic structure and bonding at Advanced Higher level. **3**

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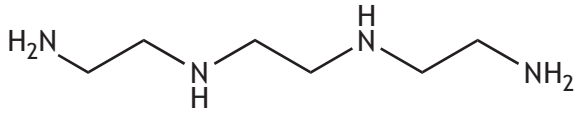
5. (continued)

[Turn over

6. Wilson's disease is a rare genetic disorder which results in a build-up of copper ions in the body. Unmetabolised copper ions are toxic, leading to health complications.

Copper ions can be removed by reaction with trientine.



trientine

(a) Trientine is a tetradentate ligand that reacts with copper(II) ions in a 1:1 ratio to form a complex ion which can then be removed from the body.

(i) Ligands form dative covalent bonds with metal ions.

State what is meant by a dative covalent bond. **1**

(ii) Draw a structural formula for the complex ion. **1**

6. (continued)

(b) Zinc ethanoate can also be used to treat Wilson's disease.

(i) Zinc ethanoate can be prepared from zinc hydroxide and ethanoic acid.

Name this type of reaction. **1**

(ii) Zinc ethanoate is a salt of a weak acid.

State what is meant by a weak acid. **1**

(iii) A student carried out an experiment to determine the value of y in hydrated zinc ethanoate, $Zn(CH_3COO)_2.yH_2O$. A 5·00 g sample was heated until all the water was removed and a constant mass of 4·18 g was obtained.

(A) Name the piece of apparatus that should be used to store the zinc ethanoate while cooling. **1**

(B) Calculate the value of y. **2**

(C) The student repeated the experiment with a second sample of hydrated zinc ethanoate.

The student's calculations were correct but the value of y was found to be different from the expected value.

Suggest a reason for this difference. **1**

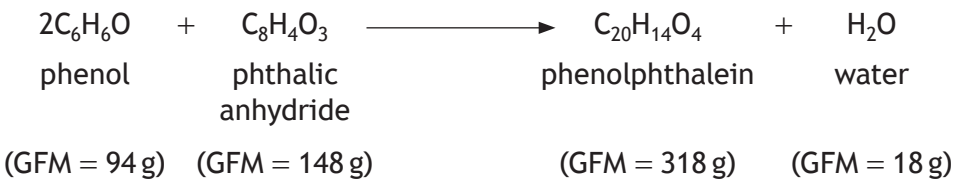
7. Phenolphthalein is an indicator that can be prepared by the reaction of phenol with phthalic anhydride.

(a) Phenolphthalein prepared by this method can have insoluble impurities present. It can be purified by recrystallisation from an aqueous ethanol solution.

(i) Outline the steps that should be carried out to recrystallise phenolphthalein. **2**

(ii) Name a technique that could be used to determine if the recrystallised phenolphthalein is pure. **1**

(b) The equation for the reaction is given below.



0·96 g of phenol is reacted with 1·05 g phthalic anhydride.

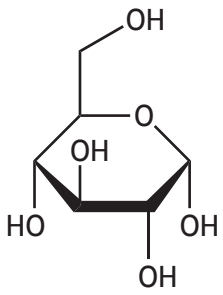
In an experimental procedure, the percentage yield of phenolphthalein was 58%.

Calculate the mass, in grams, of phenolphthalein produced. **3**

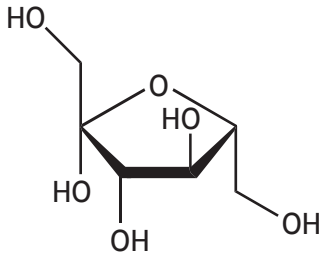
8. High levels of sugar in foods are associated with obesity. Sugars are also the basis of many medicines.

(a) Glucose-fructose syrup is a type of sugar that is added to many foods. It is a mixture of glucose and fructose.

The ring structures of glucose and fructose are shown below.



glucose



fructose

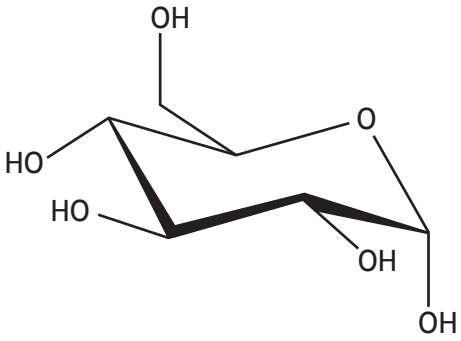
(i) Write the molecular formula for fructose. **1**

(ii) Suggest, with reference to the structures, how ^{1}H NMR spectroscopy could be used to distinguish between glucose and fructose. **1**

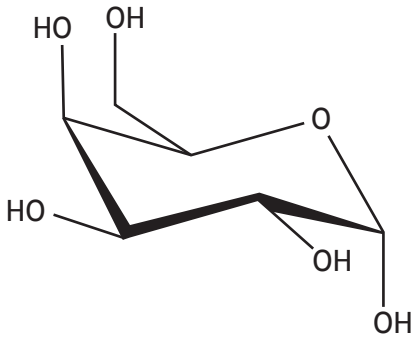
[Turn over

8. (continued)

(b) A more accurate representation of the structure of glucose, and its geometric isomer galactose, is shown below.



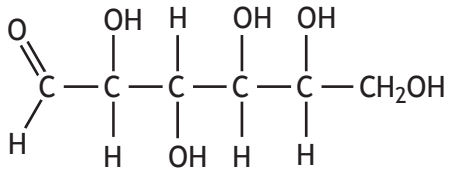
glucose



galactose

With reference to the structures shown, explain why sugars such as glucose and galactose have geometric isomers. **1**

(c) The ring structure of glucose exists in equilibrium with its open-chain structure. The diagram below shows the open-chain structure of one optical isomer of glucose called D-glucose.



D-glucose

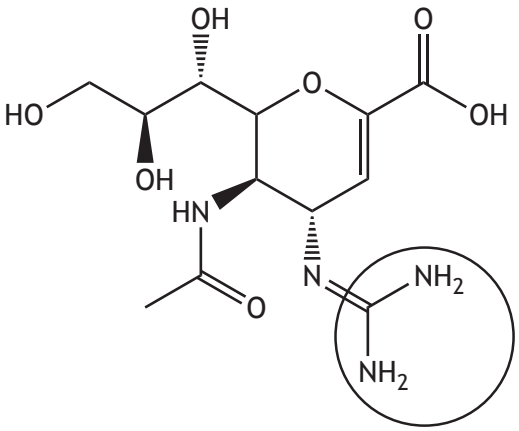
(i) State the number of chiral centres in D-glucose. **1**

(ii) Draw an open-chain structural formula for an optical isomer of D-glucose. **1**

8. (continued)

(d) Relenza is a sugar-based medicine used to treat the flu virus. It acts by attaching to an enzyme active site on the virus.

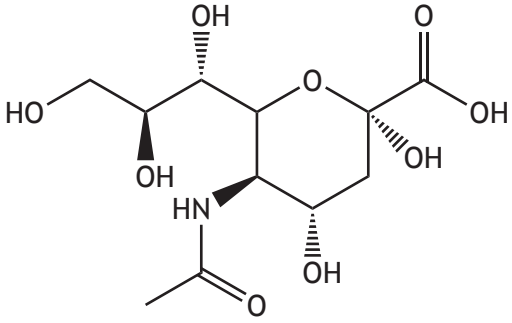
The structure of Relenza is shown.



Relenza

(i) Suggest how the functional groups circled on the Relenza molecule would bind with part of the enzyme active site. **1**

(ii) The structure of the natural active compound, sialic acid, is shown.



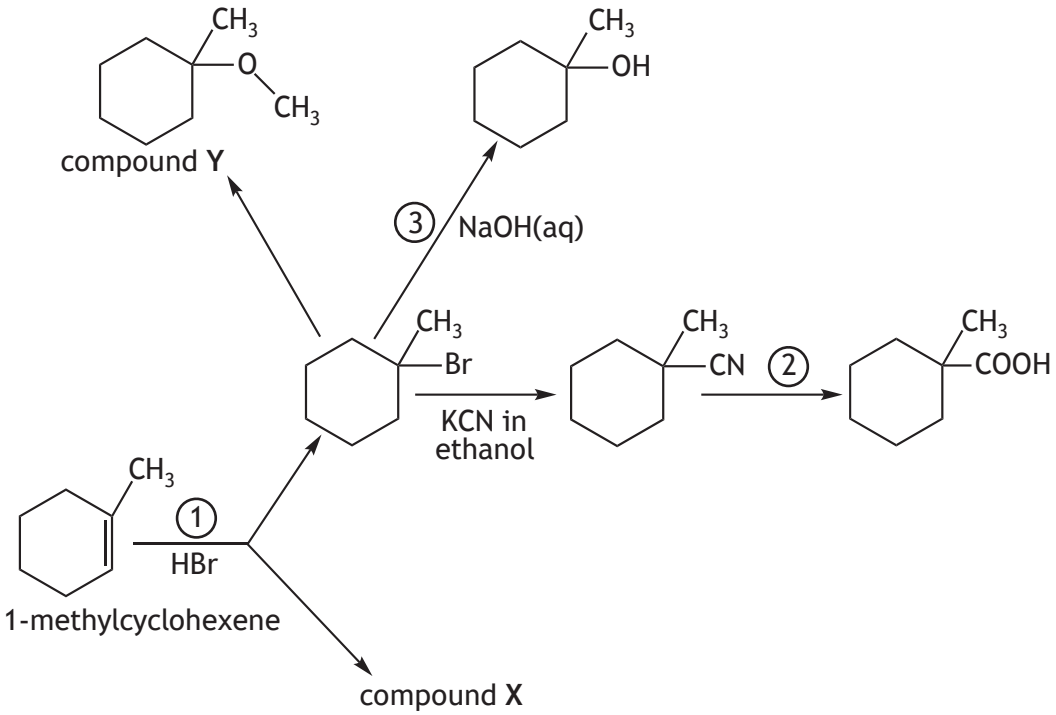
sialic acid

Sialic acid binds to the same part of the enzyme active site as Relenza.

Circle the functional groups on the sialic acid molecule which are most likely to bind with the enzyme active site.

(An additional diagram, if required, can be found on *Page 28*) **1**

9. A student devised the following reaction scheme starting with 1-methylcyclohexene.



(a) In reaction ①, 1-methylcyclohexene reacts with HBr to produce two compounds.

(i) Draw a structural formula for compound **X**. **1**

(ii) Reaction ① obeys Markovnikov's rule.

Explain, with reference to the carbocation intermediate, why compound **X** is the minor product in this reaction. **1**

9. (continued)

(b) Suggest a reagent that could be used in reaction ②. **1**

(c) Reaction ③ is likely to undergo an S_N1 mechanism.
Using curly arrow notation, draw the mechanism for this reaction. **2**

(d) Name compound **Y**. **1**

[Turn over

10. An active ingredient in many stain removing products is the oxidising agent hydrogen peroxide, H_2O_2.

(a) In an experiment to determine the concentration of hydrogen peroxide present in a stain remover a student carried out a titration with acidified permanganate solution.

$$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

$5{\cdot}0\,cm^3$ of stain remover was pipetted into a $100\,cm^3$ standard flask and made up to the mark with distilled water.

$20{\cdot}0\,cm^3$ samples were titrated with $0{\cdot}030\,mol\,l^{-1}$ permanganate solution until a permanent pink colour remained. The results are shown in the table.

	1st titration	2nd titration	3rd titration
Initial burette reading (cm^3)	0·3	19·2	0·2
Final burette reading (cm^3)	19·2	37·7	18·8
Volume used (cm^3)	18·9	18·5	18·6

(i) Calculate the number of moles of hydrogen peroxide in $20{\cdot}0\,cm^3$ of the diluted solution of stain remover. **2**

(ii) Calculate the concentration, in $mol\,l^{-1}$, of hydrogen peroxide in the undiluted stain remover. **2**

10. (a) (continued)

(iii) The concentration of hydrogen peroxide determined by the student was less than the concentration stated on the label for the stain remover.

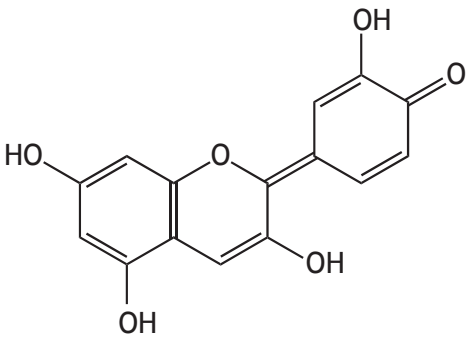
One possible source of error could be an inaccurate concentration of the permanganate solution.

Describe how the student would confirm the concentration of the permanganate solution. **1**

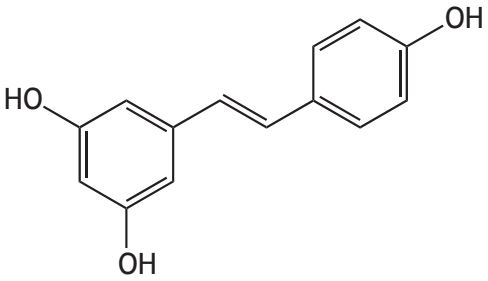
[Turn over

10. (continued)

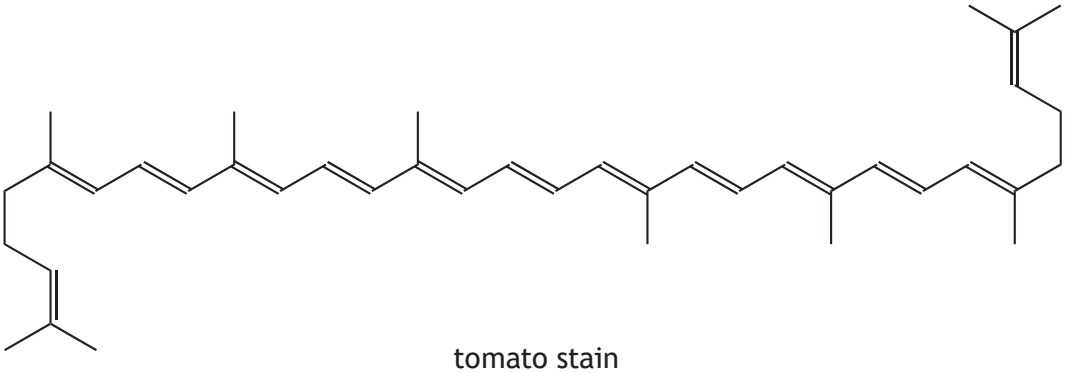
(b) Some of the molecules thought to be responsible for the colour of stains are shown.



blackcurrant stain



red wine stain



tomato stain

Using your knowledge of chemistry, suggest how the chemicals in a stain remover might work on these stains. **3**

10. (b) (continued)

[Turn over

11. Nutmeg is a seed that is commonly used as a spice in cooking. The flavour of nutmeg is due to a number of different compounds.

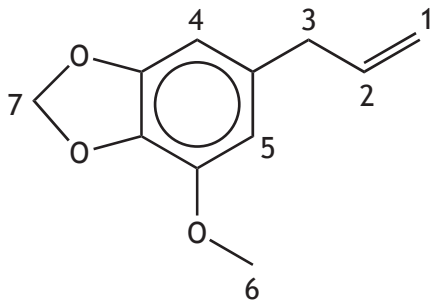
(a) The oil in nutmeg, trimyristin, can be easily extracted and purified.

In an experiment to extract trimyristin, a student refluxed nutmeg powder in a suitable solvent. Removal of the solvent produced an impure sample of solid trimyristin.

(i) Suggest why an ether could be a suitable solvent to extract trimyristin oil from nutmeg. **1**

(ii) Suggest why the mixture was heated under reflux. **1**

(b) Myristicin is another compound that can be isolated from nutmeg. ^{1}H NMR analysis showed there to be seven proton environments and these are numbered on the skeletal formula shown.



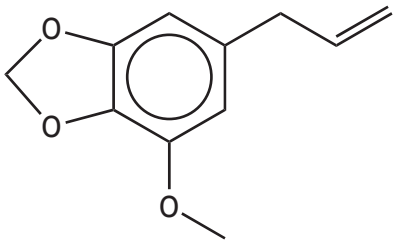
myristicin

(i) Suggest a possible chemical shift for the peak arising due to proton environment 1. **1**

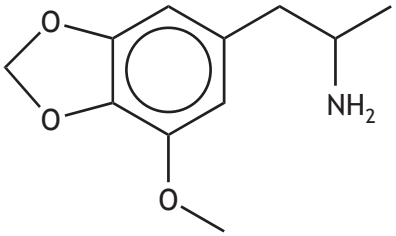
(ii) Identify a proton environment which would produce a doublet in the ^{1}H NMR spectrum. **1**

11. (continued)

(c) Myristicin can be converted into compound X in **two** steps.



myristicin



compound X

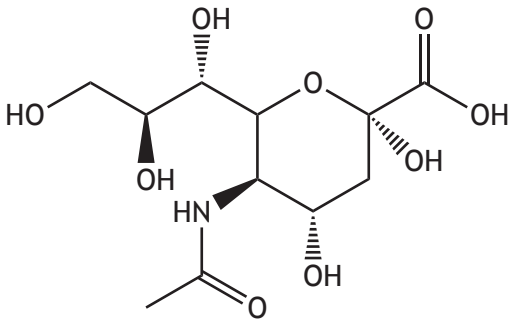
Suggest the type of reaction occurring at **each** step. **2**

Step 1:

Step 2:

[END OF QUESTION PAPER]

ADDITIONAL DIAGRAM FOR USE IN QUESTION 8 (d) (ii)



sialic acid

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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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