FOR OFFICIAL USE

National Qualifications 2024

Mark

X813/77/01

Chemistry
Section 1 — Answer grid and Section 2

THURSDAY, 23 MAY
9:00 AM – 12:00 NOON

X8137701

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 — 110

SECTION 1 — 25 marks
Attempt ALL questions.
Instructions for the completion of Section 1 are given on *page 02*.

SECTION 2 — 85 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.

SQA ©

X8137701 01

SECTION 1 — 25 marks

The questions for Section 1 are contained in the question paper X813/77/02.

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

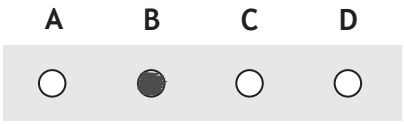
A fractional distillation

B chromatography

C fractional crystallisation

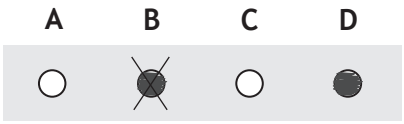
D filtration.

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

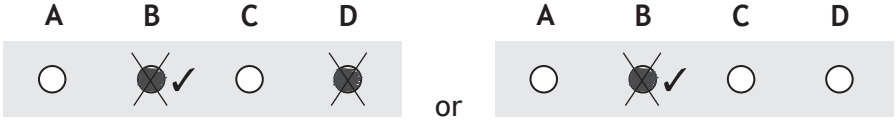


Changing an answer

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

0BJ25AD1

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

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SECTION 2 — 85 marks

Attempt ALL questions

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1. Ethanal reacts with hydroxide ions to form 3-hydroxybutanal.

(a) An experiment was carried out to determine the kinetics for the reaction.
The rate equation was found to be

$$\text{rate} = k\,[CH_3CHO(aq)]\,[OH^-(aq)]$$

(i) State the overall order of the reaction. **1**

(ii) One set of reaction conditions gave the following data.

$[CH_3CHO(aq)]$ (mol l^{-1})	$[OH^-(aq)]$ (mol l^{-1})	Initial rate $(\text{mol l}^{-1}\,\text{s}^{-1})$
0.100	0.0150	1.72×10^{-3}

Calculate the value for the rate constant, k, including the appropriate units. **2**

(iii) The reaction mechanism is shown.

Step 1 $CH_3CHO + OH^- \rightleftharpoons {}^-CH_2CHO + H_2O$

Step 2 $CH_3CHO + {}^-CH_2CHO \rightarrow CH_3CH(O^-)CH_2CHO$

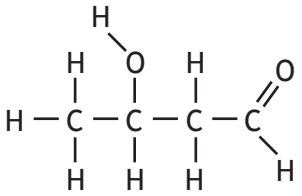
Step 3 $CH_3CH(O^-)CH_2CHO + H_2O \rightarrow CH_3CH(OH)CH_2CHO + OH^-$

Explain which step is the rate-determining step. **1**

[Turn over

1. (continued)

(b) 3-hydroxybutanal has optical isomers due to the presence of a chiral centre.



3-hydroxybutanal

(i) Circle the chiral centre in the structure of 3-hydroxybutanal shown above. **1**

(An additional diagram, if required, can be found on *page 34*.)

(ii) A sample of 3-hydroxybutanal formed in another reaction was found to be optically inactive.

State why this sample is optically inactive. **1**

2. The spiciness of chilli peppers is due to natural substances known as capsaicinoids.

(a) To extract the capsaicinoids, a sample of dried chilli pepper was soaked in a suitable solvent. The mixture was then filtered and the solvent was evaporated.

(i) Suggest a property of a solvent that would be suitable for use in this extraction. **1**

(ii) State how the filtration should be carried out to ensure a fast method of separation. **1**

(b) The spiciness of chilli peppers can be compared by using Scoville heat values.

Scoville heat value = 16.1 × concentration, in ppm, of capsaicinoids in dried chilli pepper

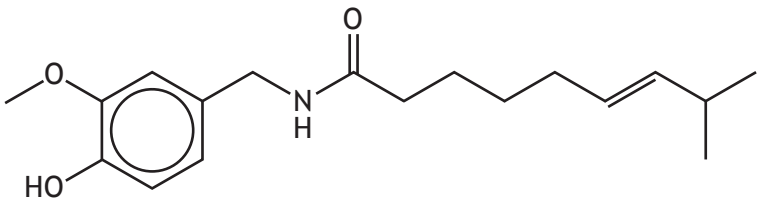
It was found that 2.00 g of dried chilli peppers contained 17.4 mg of capsaicinoids.

Calculate the Scoville heat value for this chilli pepper sample. **1**

[Turn over

2. (continued)

(c) Capsaicin is a capsaicinoid that is used in some pain relieving creams.



capsaicin

(i) Capsaicin works as a pain reliever by binding to a receptor to stimulate a response in nerve cells.

State the classification given to drugs that act in this way. **1**

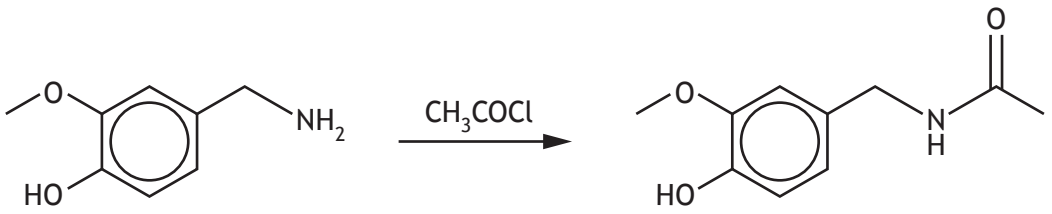
(ii) One pain relieving cream contains 1.15×10^{-4} mol of capsaicin in a 42.5 g tube of cream.

Calculate the percentage by mass of capsaicin in this cream. **1**

(GFM of capsaicin = 305 g)

2. (continued)

(d) Synthetic capsaicinoids can be prepared using vanillyl amine, as shown.

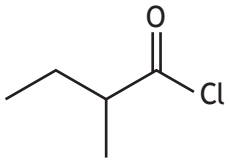


vanillyl amine synthetic capsaicinoid

(i) State the class of compounds to which CH_3COCl belongs. **1**

(ii) Suggest the type of reaction taking place. **1**

(iii) Vanillyl amine reacts with the following compound to produce a different synthetic capsaicinoid.

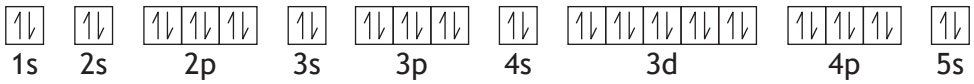


Draw a structure for the synthetic capsaicinoid produced. **1**

[Turn over

3. Human bones and teeth contain traces of strontium.

(a) The electronic configuration of a strontium atom can be written in orbital box notation, as shown.



(i) Explain how this orbital box notation shows that electrons within strontium atoms are arranged according to the Pauli exclusion principle. **1**

(ii) State one possible set of quantum numbers for an electron in the 5s orbital of strontium. **1**

3. (continued)

(b) Traces of strontium in archaeological bone samples can be used to investigate the diets of people in the past.

Strontium in bone samples can be detected by atomic emission spectroscopy.

(i) Explain how a line is produced in an emission spectrum. **1**

(ii) The spectral line used to detect strontium in a bone sample has an energy value of 251 kJ mol^{-1}.

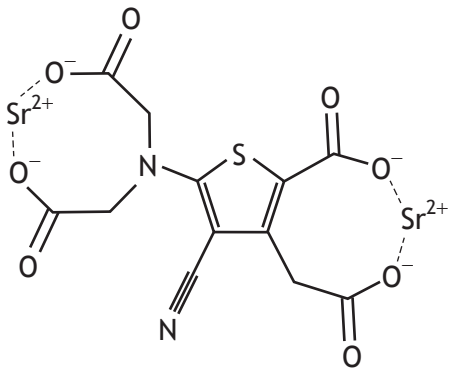
Calculate the wavelength, in nm, of this spectral line. **2**

[Turn over

3. (continued)

(c) Osteoporosis is a bone disease that can be treated with strontium ranelate.

Strontium ranelate is a complex made up of strontium ions and a ranelate ion ligand. The structure of the complex is shown.



strontium ranelate

(i) Determine the coordination number of one of the strontium ions in this complex. **1**

(ii) State the term used to classify the type of ligand in this complex. **1**

3. (continued)

(d) Strontium chloride is added to some toothpastes to reduce tooth sensitivity.

An experiment was carried out to find the value of n in the formula of hydrated strontium chloride, $SrCl_2.nH_2O$. The experimental method is outlined below.

Step 1 Weigh accurately approximately 2.5 g of $SrCl_2.nH_2O$ into a crucible of known mass.

Step 2 Heat the sample to constant mass.

(i) State what is meant by the term weigh accurately approximately. **1**

(ii) Outline the steps required to heat the sample to constant mass. **2**

(iii) The following results were obtained.

Mass of crucible	= 14.87 g
Mass of crucible and $SrCl_2.nH_2O$	= 17.58 g
Mass of crucible and $SrCl_2$	= 16.49 g

Calculate the value of n in $SrCl_2.nH_2O$. **2**

(*Clearly show your working for the calculation.*)

[Turn over

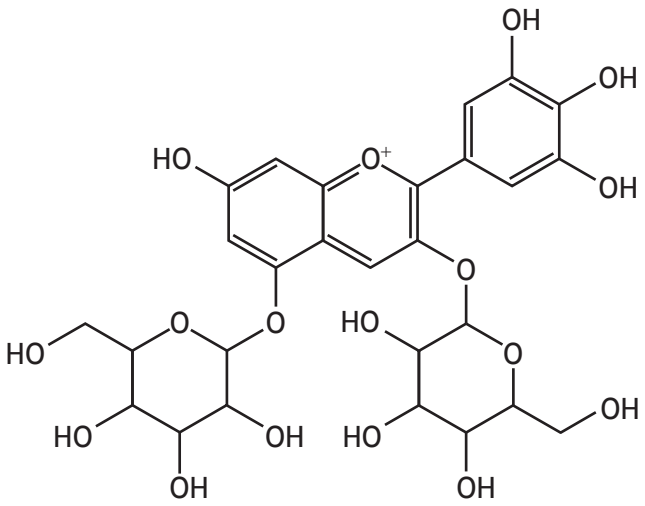
4. The colours of crocus flowers are due to pigments.

(a) The purple colour of crocus petals is due to pigments known as delphinidins.

(i) Delphinidins contain a chromophore.

Circle the part of the structure below that contains the chromophore. **1**

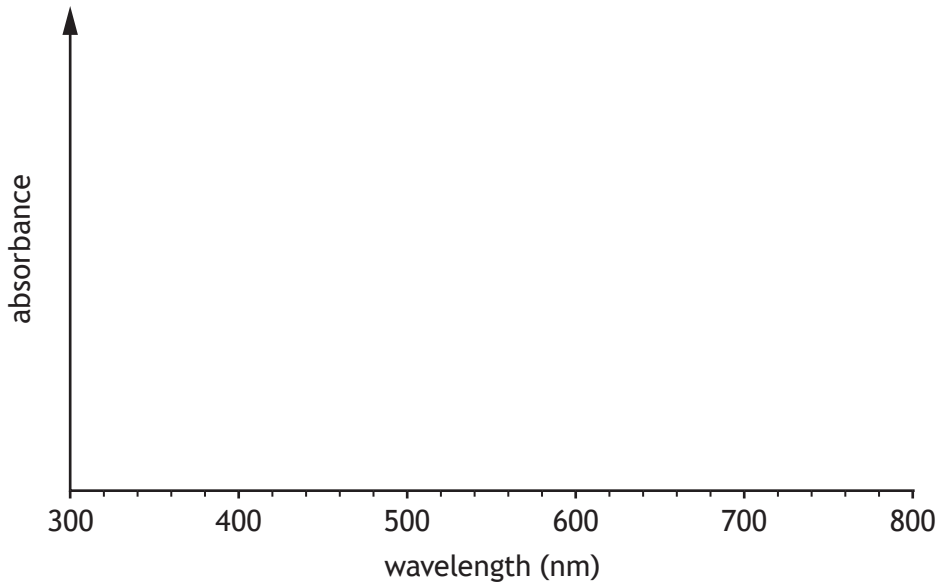
(An additional diagram, if required, can be found on *page 34*.)



a delphinidin

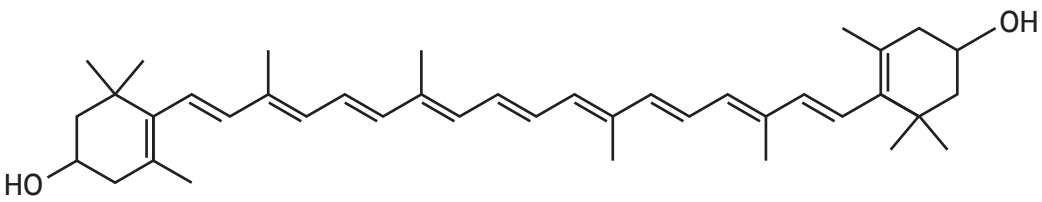
(ii) Complete the diagram below to show an absorption spectrum for a purple delphinidin. **1**

(An additional diagram, if required, can be found on *page 35*.)



4. (continued)

(b) Saffron is a spice obtained from crocus flowers. The yellow colour of saffron is partly due to the pigment zeaxanthin.



zeaxanthin

In this structure of zeaxanthin the carbon-carbon double bonds are represented by two lines.

Describe, in terms of overlapping orbitals, what each of the two lines in a double bond represent. **2**

(c) Explain fully why different pigments absorb different wavelengths of light. **2**

[Turn over

5. A student wanted to determine the composition and purity of the bright green crystals of potassium trioxalatoferrate(III), $K_3[Fe(O_2C_2O_2)_3].3H_2O$, that they had prepared.

Using your knowledge of chemistry, discuss techniques that the student could use to determine the composition and purity of the crystals. **3**

6. NMR spectroscopy can be used to detect the chemical environments of ^{1}H atoms in molecules.

(a) (i) State the type of electromagnetic radiation used in NMR spectroscopy. **1**

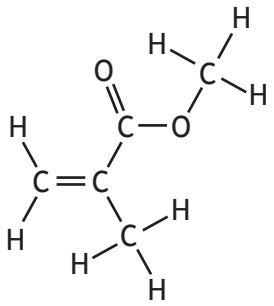
(ii) Name the standard reference substance used to give the peak at 0 ppm in a ^{1}H NMR spectrum. **1**

(b) Methyl methacrylate is an ester used in some gel nail polishes.

(i) A ^{1}H NMR spectrum of methyl methacrylate has a peak at 1.9 ppm.

On the structure below, circle a hydrogen atom that gives rise to this peak. **1**

(An additional diagram, if required, can be found on *page 35*.)

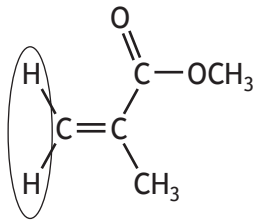


methyl methacrylate

[Turn over

6. (b) (continued)

(ii) The hydrogen atoms circled on the structure below are in two different environments.



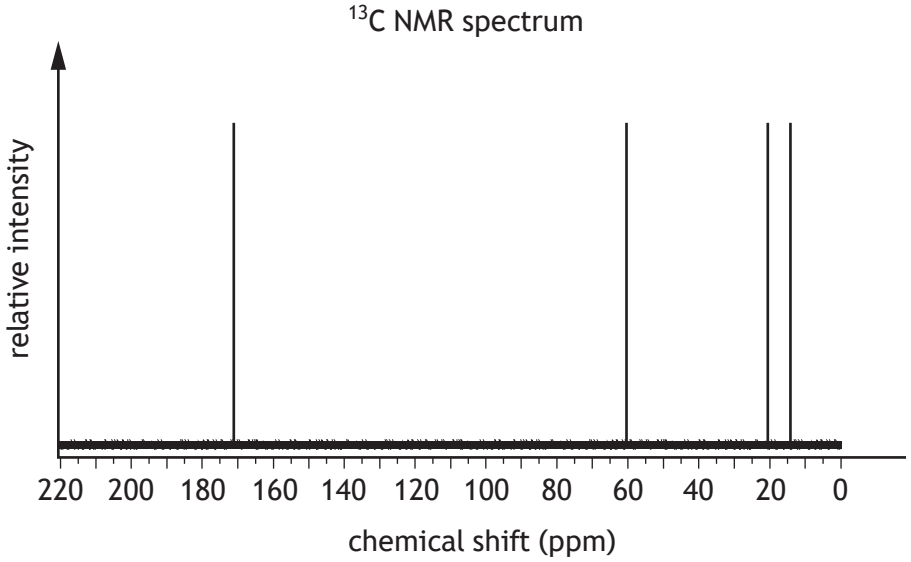
methyl methacrylate

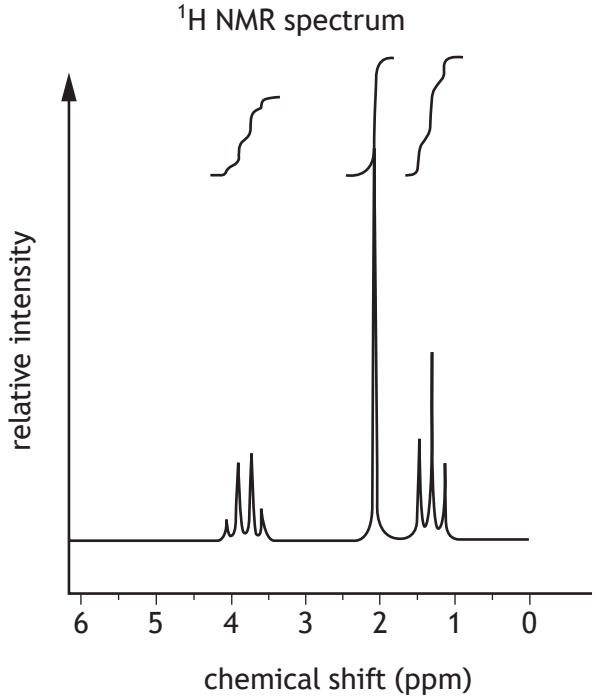
Suggest why these hydrogen atoms are in two different environments. **1**

(iii) Nuclei of the isotope ^{13}C behave in a similar way to ^{1}H nuclei in a magnetic field. ^{13}C NMR spectra have peaks, each representing a different carbon environment in a molecule.

Predict the number of peaks that would be seen in the ^{13}C NMR spectrum of methyl methacrylate. **1**

(c) The ^{13}C and ^{1}H NMR spectra of a different ester are shown below.

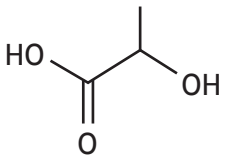




Using the data from these spectra, draw a possible structural formula for this ester. **1**

7. Fresh milk contains the sugar lactose and calcium ions.

(a) Bacteria in milk slowly convert lactose into lactic acid, lowering the pH.



lactic acid

(i) Write the molecular formula for lactic acid. **1**

(ii) A sample of milk was found to have a lactic acid concentration of 1.12×10^{-5} mol l^{-1}.

Calculate the pH of a solution of lactic acid ($K_a = 1.38 \times 10^{-4}$) with a concentration of 1.12×10^{-5} mol l^{-1}. **2**

7. (continued)

(b) The concentration of calcium ions in milk can be determined by volumetric titration with EDTA. Calcium ions react with EDTA in a 1:1 ratio.

(i) State the name given to this type of titration. **1**

(ii) To determine the mass of calcium ions in milk, 10.0 cm^3 samples of milk were titrated with 0.0200 mol l^{-1} EDTA solution. The average titre volume was found to be 14.9 cm^3.

Calculate the mass, in mg, of calcium ions in 100 cm^3 of this milk. **2**

[Turn over

8. Sulfur trioxide and sulfur dioxide are two oxides of sulfur.

(a) Sulfur trioxide decomposes to form sulfur dioxide and oxygen.

$$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g) \qquad \Delta H = +196 \text{ kJ mol}^{-1}$$

(i) Write an expression for the equilibrium constant, K, for this reaction. **1**

(ii) In an experiment to determine the equilibrium constant, K, 0.700 moles of sulfur trioxide were placed in a sealed 1.00 litre container and heated to temperature T_1.

At equilibrium the mixture contained 0.125 moles of O_2.

Calculate the equilibrium constant, K, for the reaction at T_1. **2**

(iii) The experiment was repeated at the same temperature, T_1, using 0.700 moles of sulfur trioxide in a sealed 2.00 litre container.

State the effect of this change in volume on the value of the equilibrium constant, K. **1**

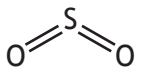
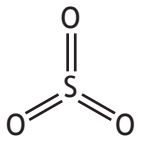
8. (a) (continued)

(iv) The experiment was then carried out using 0.700 moles of sulfur trioxide in a sealed 1.00 litre container at a different temperature, T_2.

The equilibrium constant, K, had a lower value at T_2 than at T_1.

Explain fully whether T_2 is a higher or lower temperature than T_1. **2**

(b) The table shows information about the structures of sulfur dioxide and sulfur trioxide molecules.

Molecule	Structural formula	Bond angle
Sulfur dioxide		119°
Sulfur trioxide		120°

Suggest a reason why the bond angle in sulfur dioxide is smaller than the bond angle in sulfur trioxide. **1**

[Turn over

9. The Kelpies are 30 metre high sculptures of two horses, constructed from steel.

(a) Before building the full-sized sculptures, models were constructed from steel dipped in molten zinc.

Zinc is in the d-block of the periodic table and only forms ions with an oxidation number of +2.

Explain why zinc is not considered to be a transition metal. **1**

(b) Steel can also contain manganese. The manganese content in steel can be determined by converting the manganese to an aqueous solution of purple permanganate ions, MnO_4^-.

The concentration of permanganate ions can be measured by colorimetry.

(i) The first stage is to produce a calibration graph.

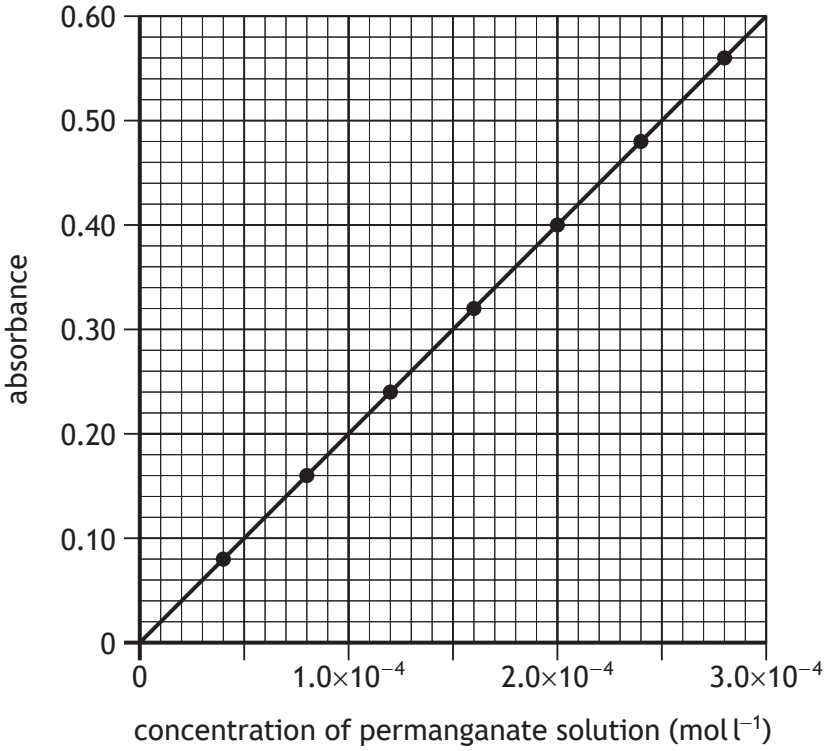
(A) A standard stock solution of potassium permanganate must be prepared.

Outline the steps required to prepare the standard stock solution from a weighed sample of solid potassium permanganate. **2**

(B) Outline the steps required to obtain results that would allow a calibration graph to be drawn. **2**

9. (b) (continued)

(ii) The following calibration graph was produced.



The manganese in a 0.285 g sample of steel was converted to permanganate ions and made up to a 500 cm^3 solution.

This solution had an absorbance of 0.28.

Calculate the percentage by mass of manganese in the steel. **2**

[Turn over

10. Epoxyethane, C_2H_4O, can be made by the oxidation of ethene.

$$C_2H_4(g) + \tfrac{1}{2}O_2(g) \rightarrow C_2H_4O(g)$$

The following information was obtained for the above reaction at 298 K.

Substance	Standard free energy of formation, $\Delta G_f°$ (kJ mol^{-1})	Standard enthalpy of formation, $\Delta H_f°$ (kJ mol^{-1})
$C_2H_4(g)$	68.2	52.4
$O_2(g)$	–	–
$C_2H_4O(g)$	–13.1	–52.6

(a) For the oxidation of ethene, calculate:

(i) the standard enthalpy change, $\Delta H°$, in kJ mol^{-1} **1**

(ii) the standard entropy change, $\Delta S°$, in J K^{-1} mol^{-1} **2**

(iii) the temperature, in K, at which this reaction becomes feasible. **2**

10. (continued)

(b) Epoxyethane is produced industrially by the oxidation of ethene using a solid silver catalyst.

$$C_2H_4(g) + \tfrac{1}{2}O_2(g) \rightarrow C_2H_4O(g)$$

State the term used to describe this type of catalyst. **1**

(c) Epoxyethane can be used to make ethane-1,2-diol.

$$CH_2CH_2O + H_2O \rightarrow HOCH_2CH_2OH$$

Suggest a name for this type of reaction. **1**

(d) The equation shows the reaction of epoxyethane with methanol.

$$2CH_2CH_2O + CH_3OH \rightarrow HO(CH_2CH_2O)_2CH_3$$

Draw a skeletal structure for the product of this reaction. **1**

(e) The equation shows the reaction of epoxyethane with ammonia.

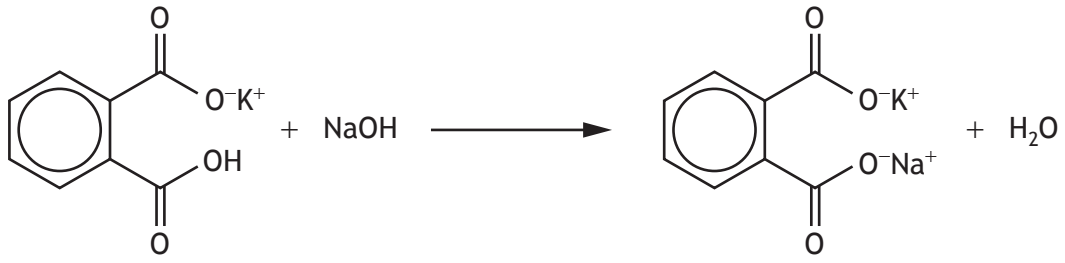
$$nCH_2CH_2O + NH_3 \rightarrow NH_{(3-n)}(CH_2CH_2OH)_n$$

Write a formula for the product when n = 3. **1**

[Turn over

11. Potassium hydrogen phthalate, KHP, is a primary standard used in volumetric analysis.

(a) To standardise a sodium hydroxide solution, a student dissolved an accurately known mass of KHP in distilled water in a conical flask and titrated it directly with the sodium hydroxide solution.

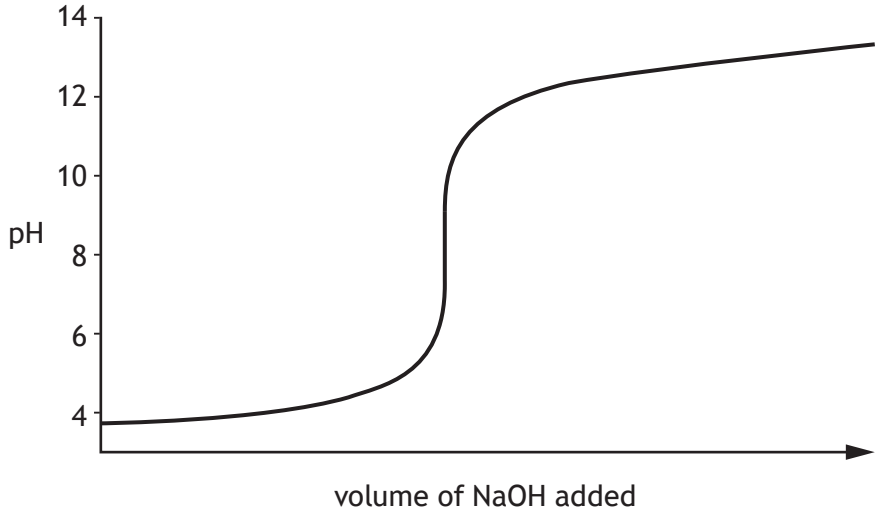


KHP

(i) Calculate the mass, in g, of KHP needed to obtain a titre volume of 15 cm^3 of 0.10 mol l^{-1} sodium hydroxide solution. **2**

11. (a) (continued)

(ii) A titration curve for the reaction between KHP and sodium hydroxide is shown.



Explain how the student would use this titration curve to select a suitable indicator for the titration. **1**

(iii) The student accurately weighed out two separate samples of KHP and titrated each of these samples using the sodium hydroxide solution.

A teacher told the student not to expect concordant titre volumes for these titrations and each volume should be used separately to calculate the concentration of the sodium hydroxide solution.

Suggest why concordant titre volumes should not be expected for these titrations. **1**

[Turn over

11. (continued)

(b) A standard solution of KHP can be used as a standard solution of carbon.

The exact mass used to prepare the standard solution depends on the purity of the KHP available.

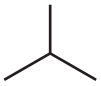
The table shows the different masses of KHP required to prepare 1 litre of a solution with a carbon concentration of 1000 ppm.

Purity of KHP (%)	Mass of KHP (g)
100	2.126
99.9	2.128
99.5	2.137
99.0	2.147

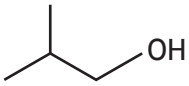
(i) Explain why the mass of KHP required increases as the purity decreases. **1**

(ii) Calculate the concentration of carbon, in ppm, of a 250 cm^3 solution prepared by dissolving 0.670 g of KHP with a purity of 99.5%. **1**

12. A student wanted to design a multi-step synthetic route to make molecule **X** from methylpropane.



methylpropane



molecule **X**

(a) Name molecule **X**. **1**

(b) The student considered that in the final step of the synthesis, molecule **X** could be made from methylpropene.

methylpropene

(i) State a reagent that could be used to carry out this step. **1**

(ii) The student realised that the major product in this step would be an isomer of molecule **X**.

Draw a structural formula for this isomer. **1**

(iii) Explain why molecule **X** would be the minor product in this step. **1**

[Turn over

12. (continued)

(c) The student devised the following reaction scheme to synthesise methylpropene from methylpropane.

methylpropane 2-chloromethylpropane methylpropene

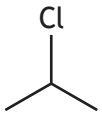
The reaction of methylpropane to make 2-chloromethylpropane involves homolytic fission.

(i) State what is meant by homolytic fission. **1**

(ii) State a reason why the yield of 2-chloromethylpropane would be very low in this reaction. **1**

12. (continued)

(d) The student wanted to design another multi-step synthetic route to make an ester from 2-chloropropane.



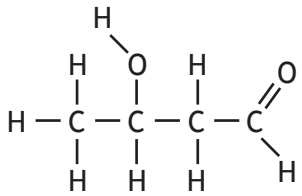
2-chloropropane

Using your knowledge of chemistry, discuss some of the reactions that would be required to synthesise an ester from 2-chloropropane. **3**

[END OF QUESTION PAPER]

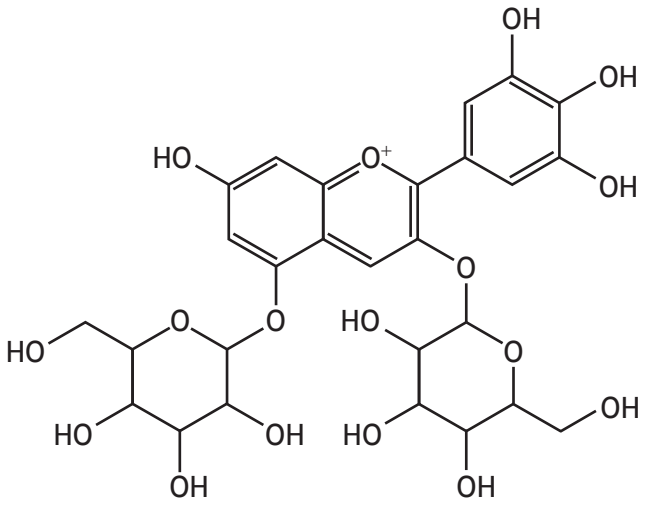
ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional diagram for use with question 1 (b) (i)



3-hydroxybutanal

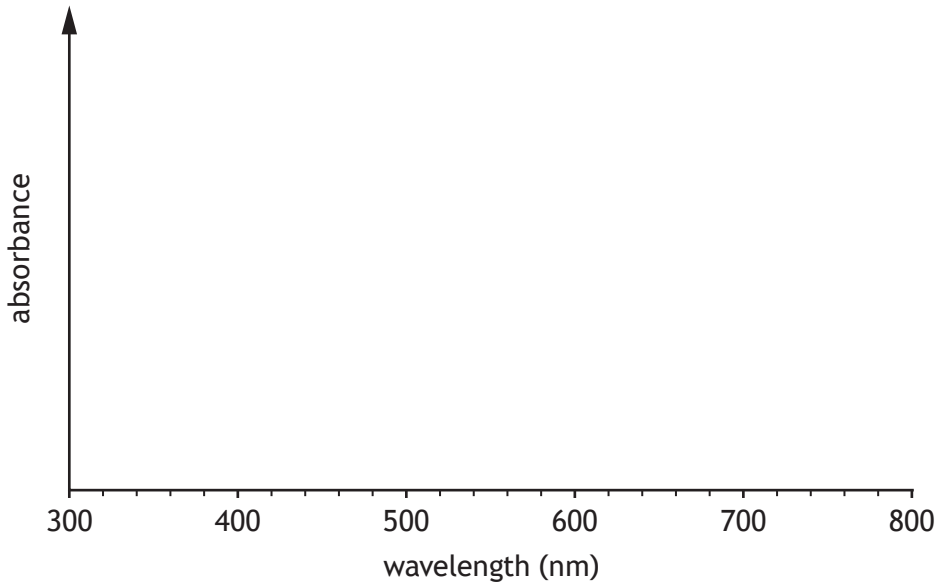
Additional diagram for use with question 4 (a) (i)



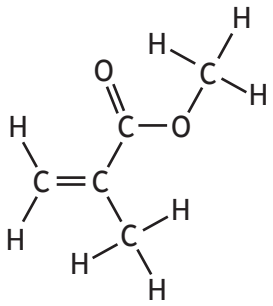
a delphinidin

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional diagram for use with question 4 (a) (ii)



Additional diagram for use with question 6 (b) (i)



methyl methacrylate

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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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