Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number ☐☐☐☐☐ Candidate Number ☐☐☐☐

Pearson Edexcel Level 3 GCE

Friday 21 June 2024

Morning (Time: 2 hours 30 minutes)

Paper reference **9CH0/03**

Chemistry

Advanced

PAPER 3: General and Practical Principles in 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 120.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*****), marks will be awarded for your ability to structure your answer logically, showing 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.
- Check your answers if you have time at the end.

Turn over ▶

Pearson

Answer ALL questions.

Write your answers in the spaces provided.

1 Relative isotopic mass is an important concept in chemistry.

(a) Define relative isotopic mass.

(2)

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(b) A sample of hydrogen gas is formed from atoms of three isotopes, ^{1}H, ^{2}H and ^{3}H.

Deduce the number of peaks due to molecular ions, H_2^+, in the mass spectrum of this sample.

(1)

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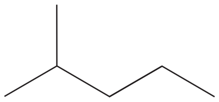
(Total for Question 1 = 3 marks)

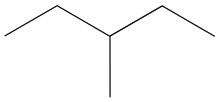
2 This question is about the intermolecular forces in organic compounds.

The structures of four isomeric alkanes are shown.

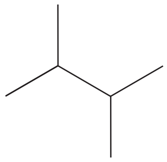
compound **A**



compound **B**



compound **C**



compound **D**

The only significant intermolecular forces between molecules of these compounds are London forces.

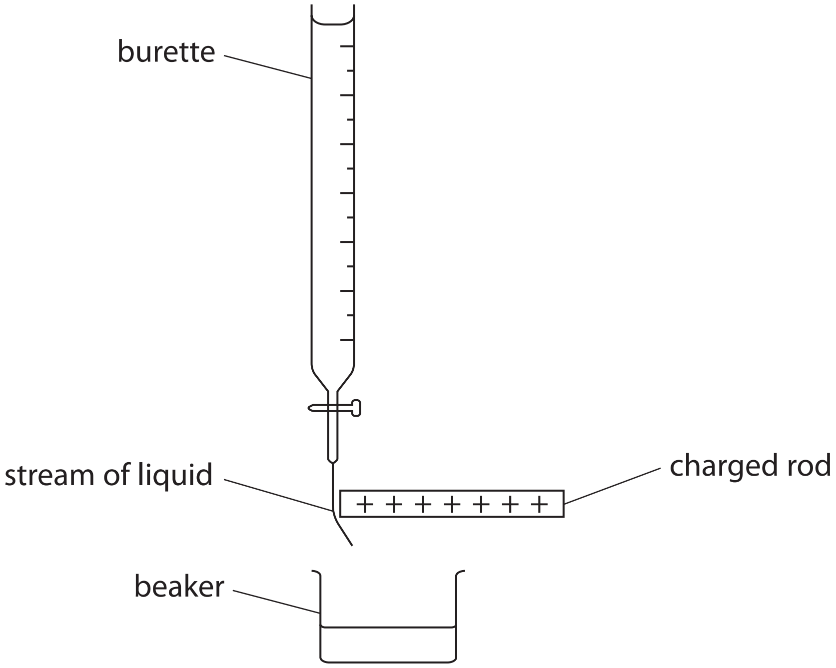
(a) Explain how London forces arise.

(3)

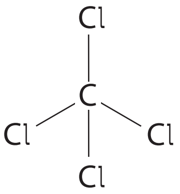
(b) Explain which of the compounds **A**–**D** will have the highest boiling temperature.

(2)

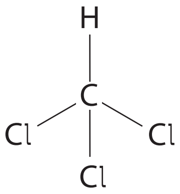
(c) The apparatus shown may be used in an experiment to compare how far, if at all, a charged rod deflects different liquids.



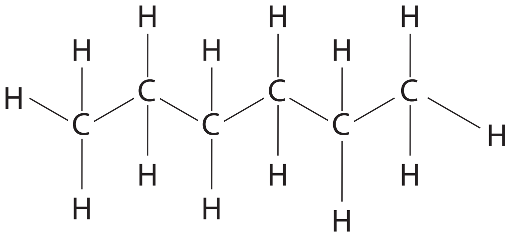
The structures of three liquids are shown.



CCl_4



$CHCl_3$



C_6H_{14}

Explain whether or not each of these liquids will be deflected in this experiment.

(3)

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(Total for Question 2 = 8 marks)

3 A student carried out an experiment to identify the Group 1 metal ion, M^+, in a sulfate, M_2SO_4.

Procedure

Step **1** A 0.48 g sample of M_2SO_4 was added to about 50 cm^3 of deionised water in a beaker. The mixture was stirred with a glass rod until the sample dissolved completely.

Step **2** An excess of acidified barium chloride solution, $BaCl_2(aq)$, was added very slowly to the solution from Step **1** to ensure the crystals of barium sulfate that formed were as large as possible.

Step **3** The barium sulfate crystals were collected by gravity filtration onto a dry filter paper of known mass.

Step **4** The crystals were rinsed using deionised water.

Step **5** The filter paper containing the crystals was dried in a warm oven for an hour and then weighed.

Results

Mass of dry filter paper = 0.17 g

Mass of dry filter paper and barium sulfate crystals = 1.19 g

(a) Give a reason, with reference to the filtration in Step **3**, why the formation of **extremely** small crystals in Step **2** would lead to a lower mass of dry barium sulfate in Step **5**.

(1)

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(b) Explain why the crystals are rinsed in Step **4**.

(2)

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(c) Calculate the relative formula mass of M_2SO_4 and hence identify M.

$$M_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2MCl(aq)$$

[M_r of $BaSO_4$ = 233.4]

(3)

(d) Another student carrying out the experiment placed the glass rod on the laboratory bench when the stirring was complete in Step **1**.

(i) Explain what effect this would have on the calculated value of the relative formula mass of M_2SO_4.

(2)

(ii) Describe how the student should amend the procedure.

(1)

(e) Another way to identify a metal ion is a flame test.

(i) Explain what causes the flame colour in such a test.

(2)

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(ii) Give one advantage and one disadvantage of using a flame test to identify a metal cation, rather than the method followed by the students in Steps **1**–**5**.

(2)

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(Total for Question 3 = 13 marks)

4 This question is about the white crystalline solid, barium nitrate.

(a) Barium nitrate decomposes under suitable conditions to form barium oxide, nitrogen dioxide and oxygen.

$$2Ba(NO_3)_2(s) \rightarrow 2BaO(s) + 4NO_2(g) + O_2(g) \qquad \Delta H^{\ominus} = +1010\ \text{kJ mol}^{-1}$$

Standard molar entropy data related to this reaction are shown.

Substance	Standard molar entropy, $S^{\ominus}$ / J K^{-1} mol^{-1}
$Ba(NO_3)_2(s)$	213.8
$BaO(s)$	70.4
$NO_2(g)$	240.0
$O_2(g)$	205.0

(i) Show that barium nitrate is thermally stable at 298 K.

(5)

(ii) Calculate the **minimum** temperature, in °C, at which it is thermodynamically feasible for barium nitrate to decompose.

Give your answer to an appropriate number of significant figures.

(3)

(b) Explain why calcium nitrate is less thermally stable than barium nitrate.

(3)

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(c) A qualitative test for nitrate ions involves heating an alkaline solution of the suspected nitrate with aluminium.

(i) Complete the ionic equation for this redox reaction, using oxidation numbers. State symbols are not required.

(1)

$$8Al + \ldots\ldots NO_3^- + \ldots\ldots OH^- + \ldots\ldots H_2O \rightarrow \ldots\ldots Al(OH)_4^- + \ldots\ldots NH_3$$

(ii) Describe a test to confirm that ammonia, NH_3, has been produced.

(1)

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(Total for Question 4 = 13 marks)

***5** Compare and contrast the reactions of bromine with benzene and of bromine with cyclohexene.

Consider the types of reaction that occur, the products that form, and any special conditions that may be required.
Justify your answers.

Detailed mechanisms for the reactions are **not** required.

(6)

(Total for Question 5 = 6 marks)

6 An ester **Q** has the molecular formula $C_8H_{16}O_2$.

(a) When hydrolysed, 2.07 g of **Q** formed a carboxylic acid with a 78 % yield. Once separated, the carboxylic acid was neutralised using excess sodium hydrogencarbonate solution.

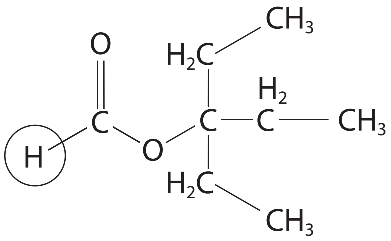
$$NaHCO_3 + RCOOH \rightarrow RCOO^-Na^+ + H_2O + CO_2$$

In this reaction, 269 cm^3 of carbon dioxide gas was produced at room temperature and pressure.

Show that these data confirm that the relative molecular mass of **Q** is 144.

(3)

(b) The high resolution proton NMR spectrum of ester **Q** was obtained.
The structure of the ester **Q** is shown.



proton environment A

(i) Explain the expected splitting pattern for the peak due to proton environment A circled in the structure.

(2)

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(ii) Label the structure to indicate the remaining equivalent proton environments in ester **Q**.

(1)

(iii) Predict the chemical shifts, relative peak areas and splitting patterns in the high resolution proton NMR spectrum, due to the proton environments you have labelled.
Do not consider proton environment A.

(3)

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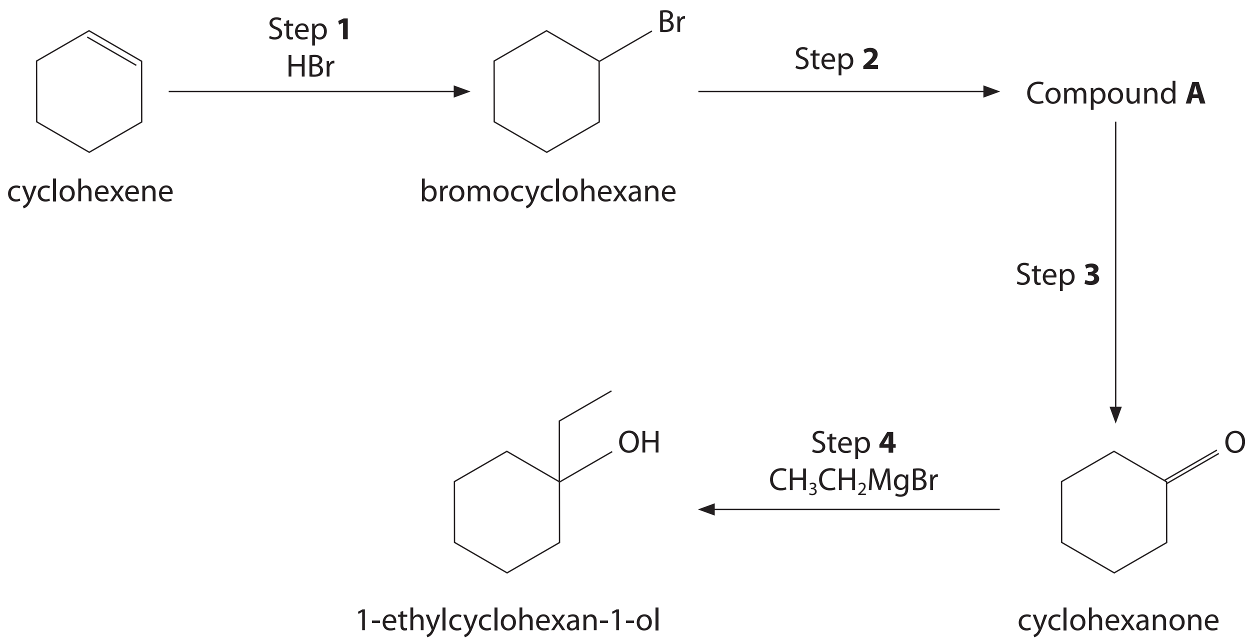
(Total for Question 6 = 9 marks)

7 The alcohol 1-ethylcyclohexan-1-ol can be synthesised from cyclohexene using the reaction scheme shown.



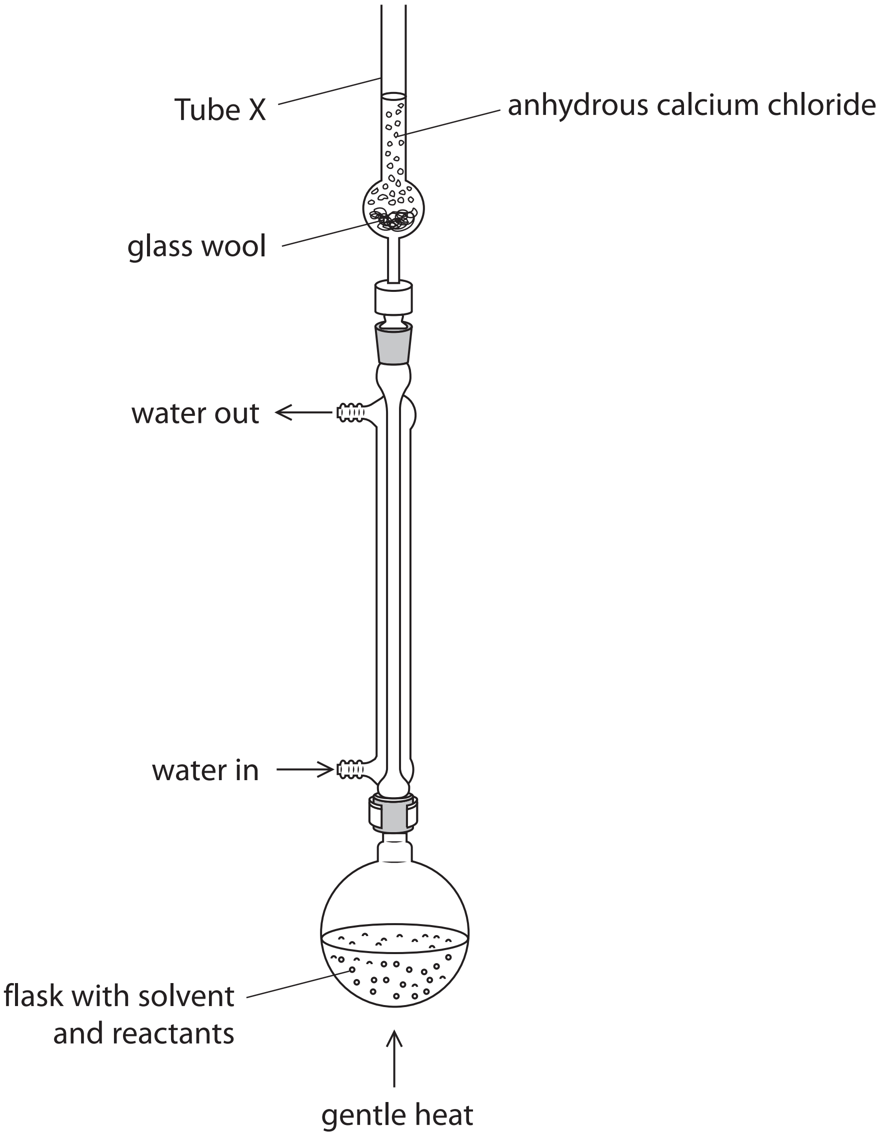
(a) Draw the mechanism for Step **1**.
Include curly arrows, and relevant lone pairs and dipoles.

(4)

(b) Devise a reaction scheme for Step **2** and Step **3** of the synthesis.
Include in your answer all reagents and conditions, the type of reaction in each step, and the structure of **A**.

(5)

(c) The reaction to produce the CH_3CH_2MgBr used in Step **4** requires bromoethane and magnesium to be warmed under reflux with a suitable solvent. The apparatus used for this reaction is shown.



(i) Name the solvent used.

(1)

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(ii) Explain why the anhydrous calcium chloride in Tube X is necessary.

(2)

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(iii) Give a reason why it is best practice for the water in the condenser to flow in the direction shown in the diagram.

(1)

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(d) Carbonyl compounds such as cyclohexanone can be identified by the reaction with 2,4-dinitrophenylhydrazine.

(i) Give the colour of the precipitate formed in this reaction.

(1)

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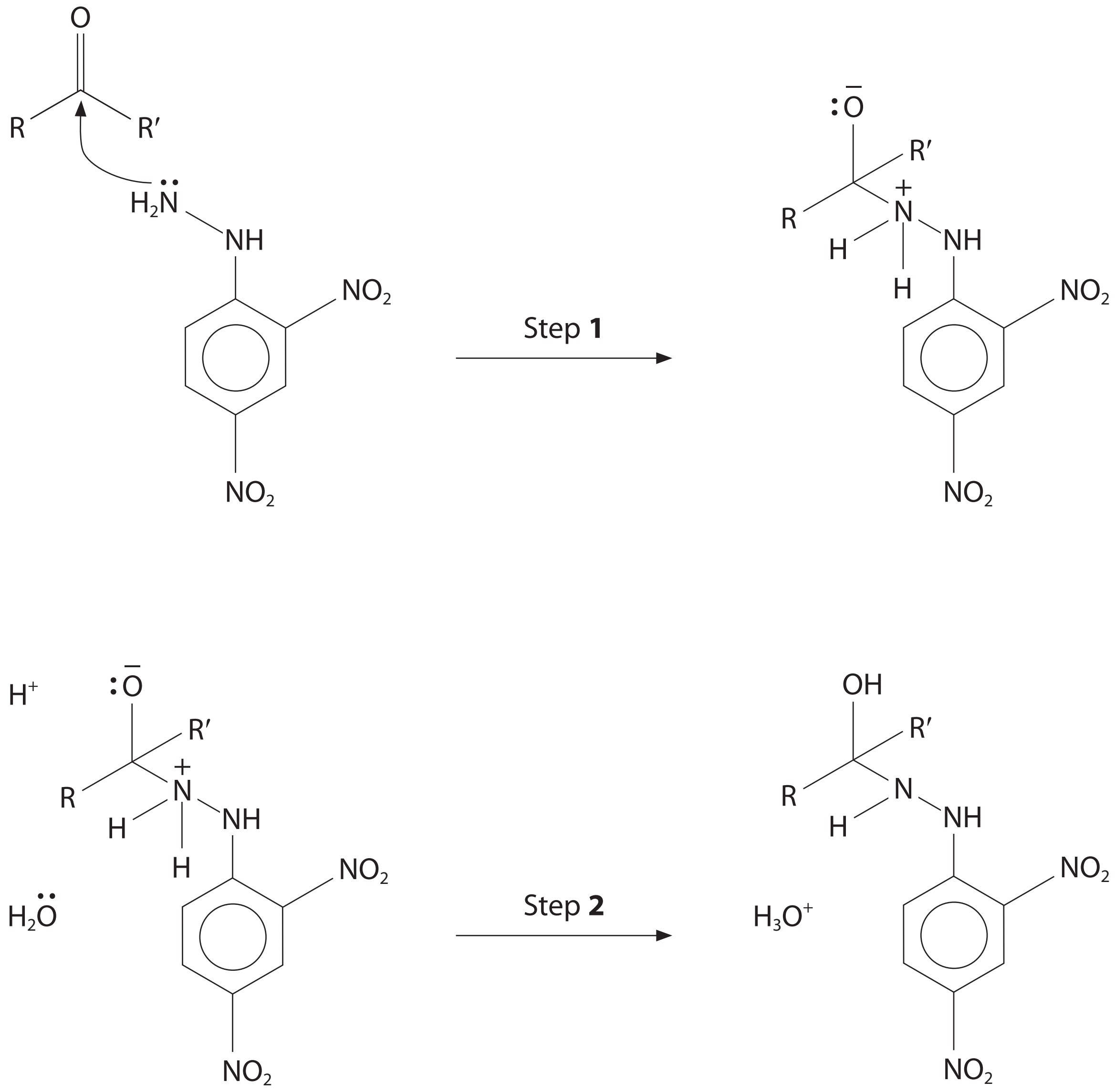
(ii) Complete the simplified mechanism for the first two steps of this reaction by adding **four** curly arrows.

(4)



(iii) Describe how you would obtain pure dry crystals from the precipitate.

(4)

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(Total for Question 7 = 22 marks)

8 This question is about acids and bases.

(a) A student devised a method to determine the acid dissociation constant, K_a, of ethanoic acid, CH_3COOH, using a solution of the acid of unknown concentration.

The student's outline procedure is shown.

Step **1** Titrate 25.0 cm^3 of the ethanoic acid solution with a solution of ammonia of known concentration, using phenolphthalein to find the end-point.

Step **2** Add a further 25.0 cm^3 of the same ethanoic acid solution to the mixture from Step **1**.
This gives a solution where the acid has been half-neutralised.

Step **3** Record the pH of the solution from Step **2**.

(i) Explain why this procedure would give invalid results.

(3)

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(ii) State how Step **1** should be amended to give valid results.

(1)

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(iii) Show that when the solution has been half-neutralised, the acid dissociation constant is given by the expression

$$K_a = 10^{-pH}$$

(3)

(b) Calculate the mass of sodium ethanoate needed to be dissolved in 250 cm^3 of 0.520 $mol\,dm^{-3}$ ethanoic acid to form a buffer solution with pH = 4.48

[K_a for ethanoic acid = 1.74×10^{-5} $mol\,dm^{-3}$]

(5)

(c) A student mixes 50.0 cm^3 of 0.900 mol dm^{-3} NaOH(aq) with 20.0 cm^3 of 0.400 mol dm^{-3} H_2SO_4(aq).

Calculate the pH of the resultant solution.

[Ionic product of water, $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}]

(5)

(Total for Question 8 = 17 marks)

9 Acidity in wine is mainly due to the dicarboxylic acid tartaric acid, $C_4H_6O_6$.

Sulfur dioxide is added to wine as an antioxidant, to prevent the colour and flavour of the wine from deteriorating. It also inhibits the growth of bacteria.

The concentration of tartaric acid and the concentration of sulfur dioxide present in wine can both be determined by titrations.

(a) The procedure to find the total amount of tartaric acid in a white wine is shown.

Step **1** Pipette a 20.0 cm^3 sample of the wine into a conical flask.

Step **2** Add anti-bumping granules to the flask, and then place it on a preheated hot plate.

Step **3** Boil the sample to remove any dissolved gases and allow it to cool.

Step **4** Use 0.100 mol dm^{-3} sodium hydroxide solution, NaOH(aq), in a burette to titrate the sample using a suitable indicator.

(i) State a precaution you would take in carrying out Step **3**.
Justify your answer.

(2)

(ii) Explain what effect the omission of Step **3** would have on the titre.

(2)

(iii) A mean titre of 20.60 cm^3 was obtained.

Calculate the concentration, in $g\,dm^{-3}$, of tartaric acid in the white wine.

$$C_4H_6O_6 + 2NaOH \rightarrow C_4H_4O_6Na_2 + 2H_2O$$

(3)

(iv) A student carrying out the experiment forgot to remove an air bubble from the tip of the burette **before** carrying out a titration. During the titration, the air bubble escaped.

Explain the effect this mistake would have on the value of this titre.

(2)

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(b) A procedure to find the amount of sulfur dioxide, SO_2, in a wine is shown.

Step **1** 50.0 cm^3 of a white wine is added to a conical flask containing 5 cm^3 of dilute sulfuric acid and a few drops of starch indicator.

Step **2** A spatula measure of sodium hydrogencarbonate is then added to reduce the loss of sulfur dioxide from the flask.

Step **3** The contents of the flask are titrated rapidly using 0.0100 mol dm^{-3} iodine solution, I_2(aq).

The equation for the reaction that takes place is shown.

$$SO_2(aq) + I_2(aq) + 2H_2O(l) \rightarrow 2I^-(aq) + 4H^+(aq) + SO_4^{2-}(aq)$$

(i) A student carrying out the experiment obtained a titre of 11.80 cm^3. The maximum permitted level of sulfur dioxide in white wine in the UK is 200 mg dm^{-3}.

Show by calculation that the concentration of sulfur dioxide in the white wine is below the permitted maximum.

(4)

(ii) Explain how the addition of sodium hydrogencarbonate in Step **2** reduces the loss of sulfur dioxide from the flask.

(2)

(Total for Question 9 = 15 marks)

10 The progress of the reaction between ethyl ethanoate and water with a hydrochloric acid catalyst can be followed in an experiment using a titrimetric method. An outline procedure is shown.

Step **1** Add 100 cm^3 of 0.500 $mol\,dm^{-3}$ $HCl(aq)$ to a conical flask.

Step **2** Using a pipette, add 5.0 cm^3 of ethyl ethanoate to the conical flask while mixing.

Step **3** Immediately remove a 5.0 cm^3 sample of the reaction mixture from Step **2** and add it to a separate conical flask containing crushed ice.

Step **4** Titrate the removed sample using 0.200 $mol\,dm^{-3}$ $NaOH(aq)$.

Step **5** Repeat Steps **3** and **4**, removing 5.0 cm^3 samples every 10 minutes.

Step **6** After 60 minutes, heat the remaining reaction mixture under reflux for 15 minutes.

Step **7** Remove a 5 cm^3 sample of the reaction mixture after completing Step **6**, titrating this sample with 0.200 $mol\,dm^{-3}$ $NaOH(aq)$.

(a) (i) Explain the purpose of the crushed ice in Step **3**.

(2)

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(ii) Explain why Step **6** is carried out before the final sample is removed and titrated in Step **7**.

(2)

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(b) Some data from the experiment are shown. V_{final} is the titre volume from Step **7**, V_t is the titre volume at time t.

Time reaction sample is added to crushed ice / min	0	10	20	30	40	50	60
$V_{final} - V_t$ of sodium hydroxide / cm^3	11.60	6.50	3.80	1.80	0.90	0.80	0.80

(i) Plot a graph of the $V_{final} - V_t$ of sodium hydroxide against the time the reaction sample is added to the crushed ice.

(3)

(ii) Explain why $V_{\text{final}} - V_t$ is plotted rather than the concentration of sodium hydroxide solution for each titre.

(2)

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(iii) Determine two half-lives for the reaction, showing your working on the graph.

(2)

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(iv) Deduce the order of the reaction, using your answer from (b)(iii) to justify your deduction.

(1)

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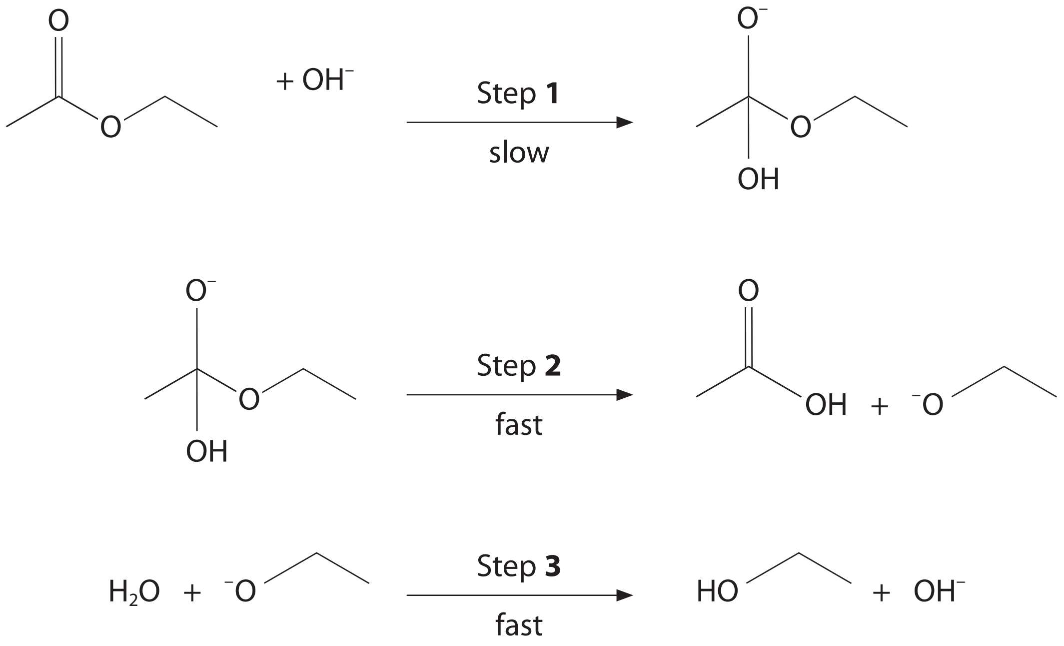
(c) Ethyl ethanoate can also be hydrolysed under alkaline conditions.

A student researching the mechanism for the reaction found this example.



Deduce a rate equation that is consistent with this reaction mechanism.
Justify your answer.

(2)

(Total for Question 10 = 14 marks)

TOTAL FOR PAPER = 120 MARKS

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
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											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							

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