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Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International Advanced Level

Centre Number | | | | | |

Candidate Number | | | | |

Thursday 14 January 2021

Afternoon (1 hour 30 minutes) | Paper Reference **WCH12/01**

Chemistry

International Advanced Subsidiary / Advanced Level
Unit 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols

You must have:
Scientific calculator, Data booklet, Ruler

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.*
- Show all your working in calculations and include units where appropriate.

Information

- The total mark for this paper is 80.
- The marks for each question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (*) marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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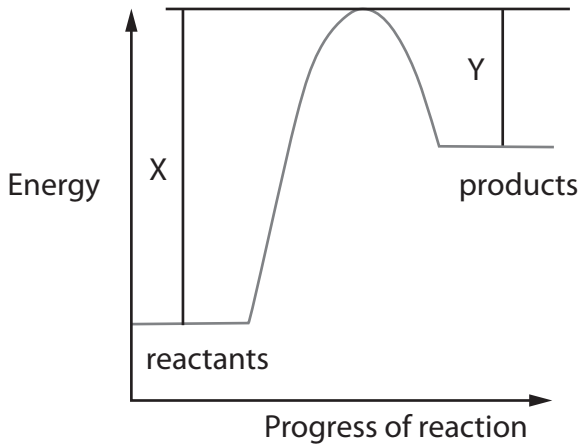
SECTION A

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 The energy profile for a reaction is shown.



What is the minimum energy needed for this reaction to occur?

☒ **A** X

☒ **B** Y

☒ **C** X – Y

☒ **D** X + Y

(Total for Question 1 = 1 mark)

2 Which of these isomers with the formula C_8H_{18} has the lowest boiling temperature?

☒ **A** $CH_3CH(CH_3)CH_2CH_2CH(CH_3)CH_3$

☒ **B** $CH_3CH(CH_3)CH_2CH_2CH_2CH_2CH_3$

☒ **C** $CH_3C(CH_3)_2CH_2CH(CH_3)CH_3$

☒ **D** $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

(Total for Question 2 = 1 mark)

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3 Which of these pure compounds has hydrogen bonding in the liquid state?

- ☒ **A** 1,1,1-trichloroethane, CH_3CCl_3
- ☒ **B** trimethylamine, $(CH_3)_3N$
- ☒ **C** hydrogen fluoride, HF
- ☒ **D** hydrogen sulfide, H_2S

(Total for Question 3 = 1 mark)

4 The hydrogen ion, H^+, bonds to a water molecule forming an H_3O^+ ion.

For H_3O^+, what shape and H-O-H bond angle are predicted by the electron-pair repulsion theory?

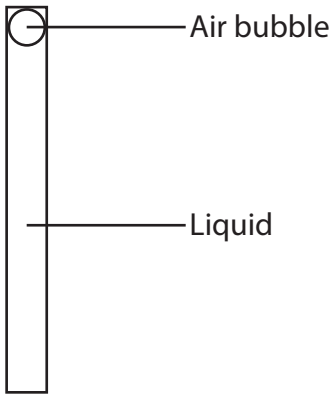
- ☒ **A** trigonal planar 120°
- ☒ **B** trigonal planar 117.5°
- ☒ **C** trigonal pyramidal 107°
- ☒ **D** trigonal pyramidal 104.5°

(Total for Question 4 = 1 mark)

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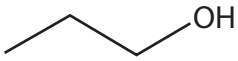
5 The viscosities of four liquid organic compounds are compared by placing the liquids in separate identical tubes, each with an air bubble at the top.



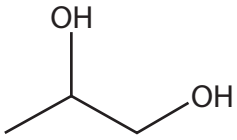
The tubes are inverted, and the times measured for the air bubble to travel the length of the tube.

For which compound does the air bubble take the longest time?

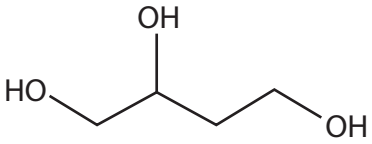
☒ **A**



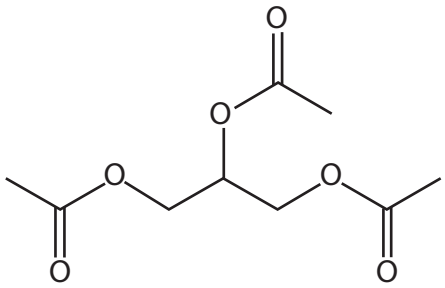
☒ **B**



☒ **C**



☒ **D**



(Total for Question 5 = 1 mark)

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6 This question is about the reaction of potassium iodide with concentrated sulfuric acid.

(a) Which of these would **not** be seen?

(1)

☒ **A** misty fumes

☒ **B** black solid

☒ **C** yellow solid

☒ **D** dense white smoke

(b) One of the reaction products is the gas H_2S.

What is the **change** in oxidation number of sulfur as H_2S forms?

(1)

☒ **A** –8

☒ **B** –6

☒ **C** –2

☒ **D** +6

(Total for Question 6 = 2 marks)

7 Iodate(V) ions, IO_3^-, oxidise dithionate ions, $S_2O_6^{2-}$, according to the equation

$$\mathbf{x}\ IO_3^- + \mathbf{y}\ S_2O_6^{2-} + 4H_2O \rightarrow \mathbf{z}\ SO_4^{2-} + 8H^+ + I_2$$

What are the balancing numbers **x**, **y** and **z**?

		x	y	z
☒	**A**	2	1	2
☒	**B**	2	2	4
☒	**C**	2	5	5
☒	**D**	2	5	10

(Total for Question 7 = 1 mark)

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8 Magnesium reacts with hydrochloric acid.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

Which statement about this reaction is correct?

- ☒ **A** magnesium atoms act as oxidising agents
- ☒ **B** hydrogen molecules act as reducing agents
- ☒ **C** hydrogen ions act as oxidising agents
- ☒ **D** chloride ions act as oxidising agents

(Total for Question 8 = 1 mark)

9 Which of these compounds does **not** produce a colour in a flame test, and produces an alkaline gas when warmed with sodium hydroxide solution?

- ☒ **A** $Ca(OH)_2$
- ☒ **B** $Mg(OH)_2$
- ☒ **C** NH_4Cl
- ☒ **D** $BeCl_2$

(Total for Question 9 = 1 mark)

10 Which of these **increases** as Group 7 is descended?

- ☒ **A** oxidising ability of the molecular halogens
- ☒ **B** reducing ability of the halide ions
- ☒ **C** electrostatic attraction between the nucleus and outer shell of electrons
- ☒ **D** electronegativity of the halogen atoms

(Total for Question 10 = 1 mark)

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11 The table shows the amount of energy released per gram when some alkanes are burned in excess oxygen under standard conditions.

Alkane	Energy released / kJ g^{-1}
methane	55.6
ethane	52.0
propane	50.4
butane	49.6

Which alkane has a standard enthalpy change of combustion of −2877 kJ mol^{-1}?

- ☒ **A** methane
- ☒ **B** ethane
- ☒ **C** propane
- ☒ **D** butane

(Total for Question 11 = 1 mark)

12 The enthalpy changes for two reactions are shown.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l) \qquad \Delta_r H = -57.2 \text{ kJ mol}^{-1}$$

$$CH_3COOH(aq) + OH^-(aq) \rightarrow CH_3COO^-(aq) + H_2O(l) \qquad \Delta_r H = -56.0 \text{ kJ mol}^{-1}$$

What is the enthalpy change for the dissociation of $CH_3COOH(aq)$ into $CH_3COO^-(aq)$ and $H^+(aq)$ ions, in kJ mol^{-1}?

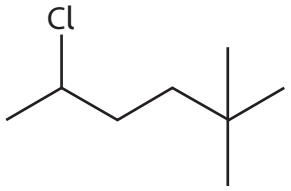
- ☒ **A** +113.2
- ☒ **B** +1.2
- ☒ **C** −1.2
- ☒ **D** −113.2

(Total for Question 12 = 1 mark)

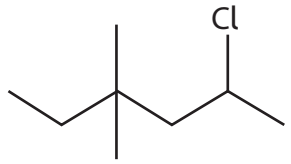
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13 What is the skeletal formula of 2-chloro-4,4-dimethylhexane?

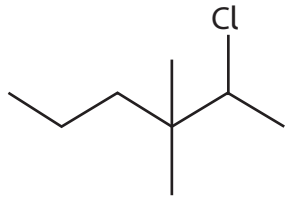
☒ **A**



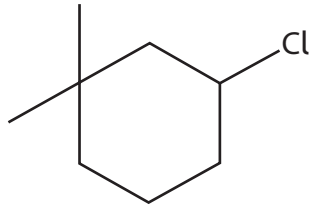
☒ **B**



☒ **C**



☒ **D**



(Total for Question 13 = 1 mark)

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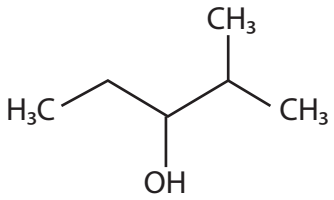
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14 Some alcohols react with concentrated phosphoric(V) acid, H_3PO_4 , to form alkenes.

(a) What type of reaction occurs?

- ☒ **A** addition
- ☒ **B** elimination
- ☒ **C** hydrolysis
- ☒ **D** substitution

(b) The structure of 2-methylpentan-3-ol is shown.



This alcohol reacts with concentrated phosphoric(V) acid.

How many different alkenes can form?

- ☒ **A** one
- ☒ **B** two
- ☒ **C** three
- ☒ **D** four

(Total for Question 14 = 2 marks)

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15 Magnesium nitrate decomposes on heating.

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

What is the total volume of gas formed at room temperature and pressure (r.t.p.) when 0.005 mol of magnesium nitrate decomposes completely?

[Molar volume of a gas at r.t.p. = 24 000 cm^3 mol^{-1}]

- ☒ **A** 600 cm^3
- ☒ **B** 300 cm^3
- ☒ **C** 240 cm^3
- ☒ **D** 120 cm^3

(Total for Question 15 = 1 mark)

16 How many moles are there in 15.1 cm^3 of liquid propan-1-ol?

[Density of propan-1-ol = 0.80 g cm^{-3} M_r of propan-1-ol = 60]

- ☒ **A** $(0.80 \times 15.1) \div 60$
- ☒ **B** $0.80 \div (60 \times 15.1)$
- ☒ **C** $60 \div (0.80 \times 15.1)$
- ☒ **D** $(60 \times 15.1) \div 0.80$

(Total for Question 16 = 1 mark)

17 The oxidation of propan-1-ol by acidified potassium dichromate(VI) forms propanoic acid with a yield of 36 % by mass.

What mass of propan-1-ol is needed to form 37.0 g of propanoic acid in this reaction?

[M_r of propanoic acid = 74 M_r of propan-1-ol = 60]

- ☒ **A** 10.8 g
- ☒ **B** 36.0 g
- ☒ **C** 40.8 g
- ☒ **D** 83.3 g

(Total for Question 17 = 1 mark)

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18 Barium chloride solution, $BaCl_2(aq)$, reacts with gallium sulfate solution, $Ga_2(SO_4)_3(aq)$ to form a precipitate of barium sulfate, $BaSO_4(s)$.

What is the minimum volume of 0.100 mol dm^{-3} barium chloride needed to precipitate **all** the sulfate ions in 200 cm^3 of 0.05 mol dm^{-3} gallium sulfate?

- ☒ **A** 100 cm^3
- ☒ **B** 200 cm^3
- ☒ **C** 300 cm^3
- ☒ **D** 400 cm^3

(Total for Question 18 = 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.

19 Ethanol can be made in industry by the reaction of ethene with steam, using a phosphoric(V) acid catalyst.

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta_r H = -45 \text{ kJ mol}^{-1}$$

The reaction is carried out at 300°C and 60 atm. An initial yield of 5 % is achieved when the ethene and steam first pass through the reactor.

*(a) Explain the chemical reasons for the conditions used and why such a low initial yield is acceptable in the industrial process.

(6)

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(b) The product of the reaction is a mixture of ethanol and water.

Explain why ethanol and water mix together fully.

You may find it helpful to draw a diagram.

(3)

(c) Ethanol can be oxidised using a solution of acidified potassium dichromate(VI), $K_2Cr_2O_7(aq)$.

Ethanoic acid and another organic compound, **Y**, are both possible products.

(i) Draw the structure of **Y**.

(1)

(ii) State the conditions needed to maximise the yield of each product.

(2)

Conditions for maximum yield of **Y**

Conditions for maximum yield of ethanoic acid

(Total for Question 19 = 12 marks)

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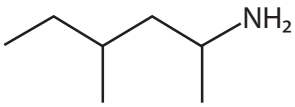
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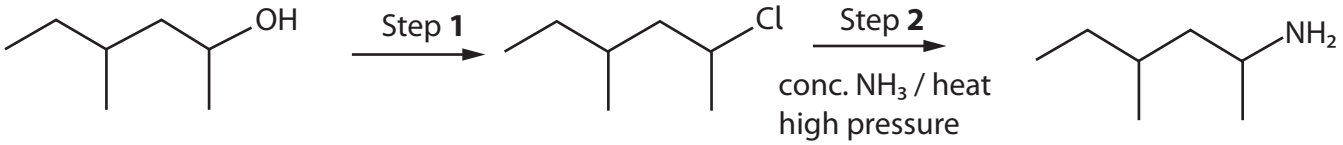
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20 The compound DMAA was originally synthesised as a decongestant.



DMAA

A suggested synthetic route for DMAA is shown.



compound **A**

(a) (i) Give the systematic name of compound **A**.

(1)

.....

(ii) Identify, by name or formula, a suitable reagent for Step **1**.

(1)

.....

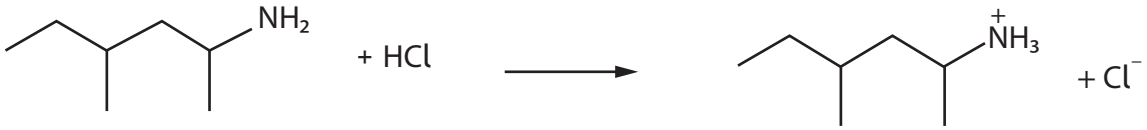
(iii) Give the mechanism for the reaction in Step **2**.
Include curly arrows, and any relevant dipoles and lone pairs.

(4)

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(b) DMAA is only slightly soluble in water but dissolves readily in hydrochloric acid to form an aqueous solution.



DMAA

(i) Explain the type of bonding that occurs between the nitrogen atom and the hydrogen ion, when the positive ion forms.

(3)

(ii) Complete the diagrams to show how the ions formed in the reaction between DMAA and hydrochloric acid interact with water molecules.

(3)



(Total for Question 20 = 12 marks)

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21 This question is about ethanoic acid and some related salts.

(a) A test to confirm the presence of an aqueous acid is adding a small amount of solid sodium carbonate to the solution.

Describe **two** observations you would **see** in this test.

(2)

.....

.....

.....

.....

(b) Sodium ethanoate is a component of reusable hand warmers.
In use, a supersaturated solution of sodium ethanoate recrystallises to form solid hydrated sodium ethanoate, releasing energy.

$CH_3COONa(aq) + 3H_2O(l) \rightarrow CH_3COONa.3H_2O(s) \quad \Delta_r H = -19.7 \text{ kJ mol}^{-1}$

A hand warmer has a mass of 63.2 g and forms 20.1 g of hydrated sodium ethanoate on recrystallisation.

Calculate the maximum temperature reached by the hand warmer if its initial temperature is 5.0°C.

[Specific heat capacity of the hand warmer = 3.0 J $°C^{-1}$ g^{-1}]

(5)

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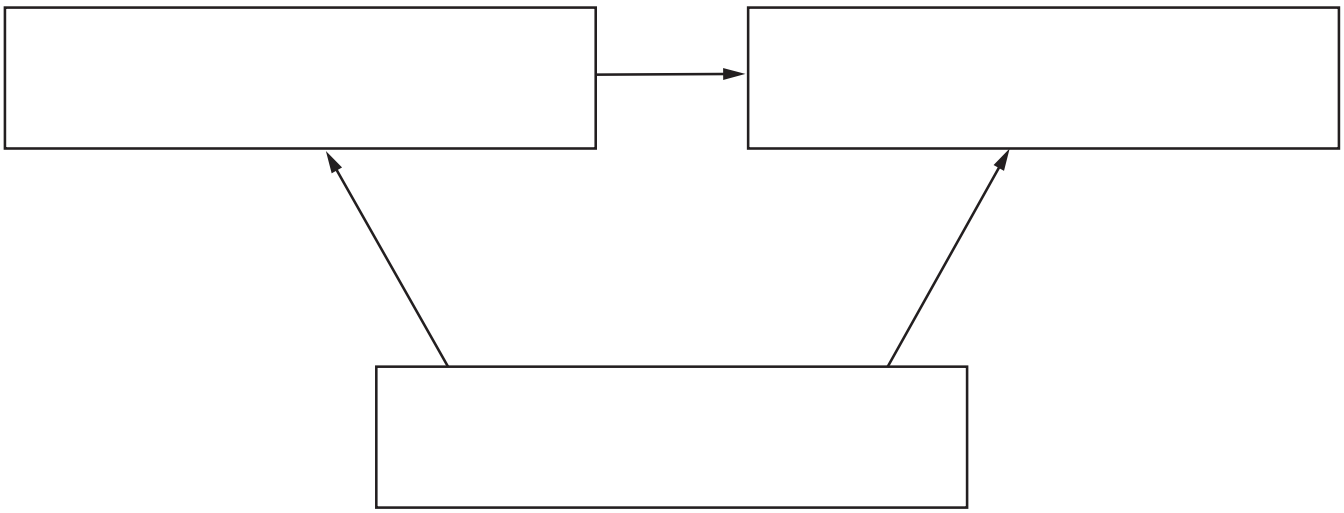
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(c) Ammonium ethanoate, $CH_3COONH_4(s)$, is used to control the pH of foods. It can be formed by the reaction of pure ethanoic acid, $CH_3COOH(l)$, with ammonium carbonate, $(NH_4)_2CO_3(s)$.

Calculate the standard enthalpy change for this reaction by completing the Hess cycle and using the data shown.

(5)



Compound	Enthalpy change of formation / kJ mol^{-1}
$CH_3COOH(l)$	–484.5
$(NH_4)_2CO_3(s)$	–939.9
$CH_3COONH_4(s)$	–586.3
$CO_2(g)$	–393.5
$H_2O(l)$	–285.8

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(d) Ammonium carbonate, $(NH_4)_2CO_3$, is an ingredient in cleaning solutions for camera lenses.

These are aqueous solutions which contain no more than 1.8 g of ammonium carbonate in 100 cm^3 of solution.

Calculate the maximum concentration, in mol dm^{-3}, of ammonium carbonate in such a solution.

(2)

(Total for Question 21 = 14 marks)

TOTAL FOR SECTION B = 38 MARKS

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SECTION C

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

22 Potassium chlorate(V), $KClO_3$, is a crystalline solid used in fireworks.

It is produced by the Liebig Process in two stages.

Stage **1** Chlorine gas is passed through hot calcium hydroxide solution forming calcium chlorate(V), $Ca(ClO_3)_2$.

$$6Ca(OH)_2(aq) + 6Cl_2(g) \rightarrow Ca(ClO_3)_2(aq) + 5CaCl_2(aq) + 6H_2O(l)$$

Stage **2** Potassium chloride solution is then added to form potassium chlorate(V).

$$Ca(ClO_3)_2(aq) + 2KCl(aq) \rightarrow 2KClO_3(aq) + CaCl_2(aq)$$

The solution is heated to reduce its volume and then allowed to crystallise.
The crystals are filtered off.
The remaining filtrate is evaporated further to obtain more crystals.

(a) (i) Write the **overall** equation for the Liebig Process.
State symbols are not required.

(1)

(ii) Calculate the **overall** atom economy by mass for the production of potassium chlorate(V), $KClO_3$, using your equation in (a)(i).

(3)

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(b) Explain the type of reaction that takes place in Stage **1** of the Liebig Process, using oxidation numbers.

$$6Ca(OH)_2(aq) + 6Cl_2(g) \rightarrow Ca(ClO_3)_2(aq) + 5CaCl_2(aq) + 6H_2O(l)$$

(3)

(c) The crystals of potassium chlorate(V) formed also contain some halide ion impurities.

(i) Describe a chemical test on a solution of these crystals to **confirm** that the impurities present are chloride ions rather than bromide ions. Include the expected results.

(3)

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(ii) 1.52 g of impure potassium chlorate(V), formed in the Liebig Process, was heated until the mass of solid remaining was constant at 1.02 g.

The reaction that occurred was

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

The impurities present did not decompose on heating.

Calculate the percentage purity of the sample.
Give your answer to an appropriate number of significant figures.

(5)

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(d) In fireworks, potassium chlorate(V) decomposes. This thermal decomposition takes place in two stages with a solid catalyst.

$$4KClO_3 \rightarrow KCl + 3KClO_4$$

$$KClO_4 \rightarrow KCl + 2O_2$$

(i) Give the systematic name of $KClO_4$.

(1)

(ii) A student investigated the role of the catalyst in this reaction.

Procedure

Step **1** Heat a sample of $KClO_3$, in a test tube, with a known mass of insoluble catalyst until the mass remains constant.

Step **2** Mix the contents of the test tube with water.

Step **3** Filter the mixture and rinse with deionised water.

Step **4** Dry the remaining solid.

Step **5** Measure the mass of the dry solid.

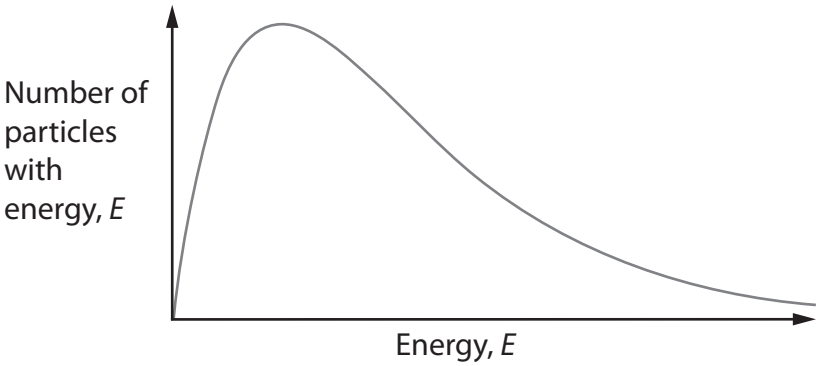
Explain how each of the steps in this procedure is needed to show that the catalyst is **not** used up in this reaction.

(4)

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(e) Explain, using the diagram, how a catalyst speeds up a chemical reaction.

(2)



(Total for Question 22 = 22 marks)

TOTAL FOR SECTION C = 22 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 lithium 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 sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

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

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