Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Tuesday 16 January 2024

Morning (Time: 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

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.*
- 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.
- There is a Periodic Table 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 ▶

P75592A

P 7 5 5 9 2 A 0 1 2 8

Pearson

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 Which compound has intermolecular hydrogen bonding?

☒ **A** HF

☒ **B** H_2Te

☒ **C** AsH_3

☒ **D** SnH_4

(Total for Question 1 = 1 mark)

2 In which process are intermolecular hydrogen bonds broken?

☒ **A** $H_2(g) \rightarrow 2H(g)$

☒ **B** $H_2O(l) \rightarrow H_2O(g)$

☒ **C** $H_2(l) \rightarrow H_2(g)$

☒ **D** $H_2(g) + ½O_2(g) \rightarrow H_2O(g)$

(Total for Question 2 = 1 mark)

3 A compound contains

- molecules with non-polar bonds
- permanent dipole-permanent dipole forces between its molecules.

What could be the formula of this compound?
Use the Data Booklet as a source of information.

☒ **A** NO

☒ **B** $BeCl_2$

☒ **C** PH_3

☒ **D** CI_4

(Total for Question 3 = 1 mark)

4 Which alkane has the strongest London forces in the liquid phase?

- ☒ **A** $(CH_3)_4C$
- ☒ **B** $CH_3CH_2CH_2CH_2CH_3$
- ☒ **C** $(C_2H_5)_4C$
- ☒ **D** $CH_3(CH_2)_7CH_3$

(Total for Question 4 = 1 mark)

5 In which liquid solvent would the solubility of lithium chloride (LiCl) be lowest?

- ☒ **A** ammonia
- ☒ **B** cyclohexane
- ☒ **C** methanol
- ☒ **D** water

(Total for Question 5 = 1 mark)

6 Which compound does **not** contain an element with an oxidation number of –1?

- ☒ **A** HF
- ☒ **B** NaH
- ☒ **C** H_2O_2
- ☒ **D** CH_4

(Total for Question 6 = 1 mark)

7 Which reaction involves the oxidation of a Group 7 element?

- ☒ **A** $Br_2 + F_2 \rightarrow 2BrF$
- ☒ **B** $U + 3ClF_3 \rightarrow UF_6 + 3ClF$
- ☒ **C** $2F_2 + 2H_2O \rightarrow 4HF + O_2$
- ☒ **D** $KCl + H_2SO_4 \rightarrow HCl + KHSO_4$

(Total for Question 7 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

8 Equal volumes of some 0.01 mol dm^{-3} solutions were mixed.

Which pair of solutions gave the greatest mass of precipitate?

- ☒ **A** $BaCl_2$ and $AgNO_3$
- ☒ **B** $BaCl_2$ and Ag_2SO_4
- ☒ **C** $BaCl_2$ and $NaNO_3$
- ☒ **D** $BaCl_2$ and Na_2SO_4

(Total for Question 8 = 1 mark)

9 Which test reagent could be used to identify an aqueous solution containing hydrogencarbonate ions, HCO_3^-?

- ☒ **A** sodium carbonate
- ☒ **B** sodium hydroxide
- ☒ **C** nitric acid
- ☒ **D** ammonia

(Total for Question 9 = 1 mark)

10 Bromine, $Br_2(l)$, can be disposed of safely by reaction with aqueous sodium thiosulfate, $Na_2S_2O_3(aq)$.

$$Br_2(l) + 2Na_2S_2O_3(aq) \rightarrow 2NaBr(aq) + Na_2S_4O_6(aq)$$

What is the minimum volume, in cm^3, of 0.5 mol dm^{-3} $Na_2S_2O_3(aq)$ needed to react completely with 0.01 mol of $Br_2(l)$?

- ☒ **A** 0.01
- ☒ **B** 0.04
- ☒ **C** 10
- ☒ **D** 40

(Total for Question 10 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

11 What is the mass of nitrogen **atoms** in 50 cm^3 of a 2.0 mol dm^{-3} solution of ammonium nitrate, $NH_4NO_3(aq)$?

- ☒ **A** 35 g
- ☒ **B** 8.0 g
- ☒ **C** 2.8 g
- ☒ **D** 1.4 g

(Total for Question 11 = 1 mark)

12 Which row shows the correct trends **down** the group for the elements of Group 7?

	Boiling temperature	Electronegativity	Reactivity as oxidising agent
☒ **A**	increases	decreases	decreases
☒ **B**	decreases	increases	increases
☒ **C**	increases	decreases	increases
☒ **D**	decreases	increases	decreases

(Total for Question 12 = 1 mark)

13 Which statement **best** explains why the rate of a chemical reaction increases with increasing temperature?

- ☒ **A** the activation energy decreases
- ☒ **B** the number of collisions increases
- ☒ **C** the kinetic energy of the particles increases
- ☒ **D** the frequency of collisions with $E \geqslant E_a$ increases

(Total for Question 13 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

14 Which statement is **not** true for a system at dynamic equilibrium?

- ☒ **A** the position of equilibrium is affected by temperature, by pressure and by catalysts
- ☒ **B** the concentration of reactants is constant
- ☒ **C** the forward and backward reactions occur at equal rates
- ☒ **D** the equilibrium can be reached from either direction

(Total for Question 14 = 1 mark)

15 Silver nitrate, in aqueous ethanol, is added separately to four halogenoalkanes.

Which would form a silver halide precipitate in the shortest time?

- ☒ **A** 1-bromobutane
- ☒ **B** 1-chlorobutane
- ☒ **C** 1-fluorobutane
- ☒ **D** 1-iodobutane

(Total for Question 15 = 1 mark)

16 What is the total number of structural isomers for cyclic alcohols with the molecular formula C_4H_8O?

- ☒ **A** 2
- ☒ **B** 3
- ☒ **C** 4
- ☒ **D** 5

(Total for Question 16 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

17 Which is a correct equation for the **incomplete** combustion of butan-1-ol?

- ☒ **A** $CH_3CH_2CH_2CH_2OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$
- ☒ **B** $CH_3CH_2CH_2CH_2OH + 6½O_2 \rightarrow 4CO_2 + 5H_2O$
- ☒ **C** $CH_3CH_2CH_2CH_2OH + 4O_2 \rightarrow 4CO + 5H_2O$
- ☒ **D** $CH_3CH_2CH_2CH_2OH + 4½O_2 \rightarrow 4CO + 5H_2O$

(Total for Question 17 = 1 mark)

18 Which reagent(s) could be used to produce a chloroalkane from a **tertiary** alcohol?

1 PCl_5

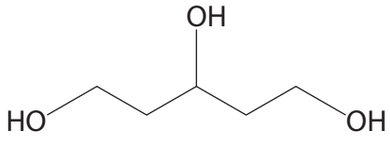
2 concentrated HCl

3 concentrated H_2SO_4 and KCl

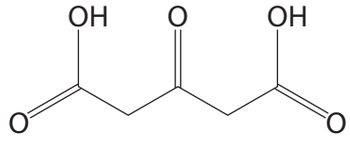
- ☒ **A** **1**, **2** and **3**
- ☒ **B** **1** and **3** only
- ☒ **C** **2** and **3** only
- ☒ **D** **1** only

(Total for Question 18 = 1 mark)

19 What amount, in mol, of [O] is needed to convert 1 mol of pentane-1,3,5-triol into 3-oxopentanedioic acid and water?



pentane-1,3,5-triol

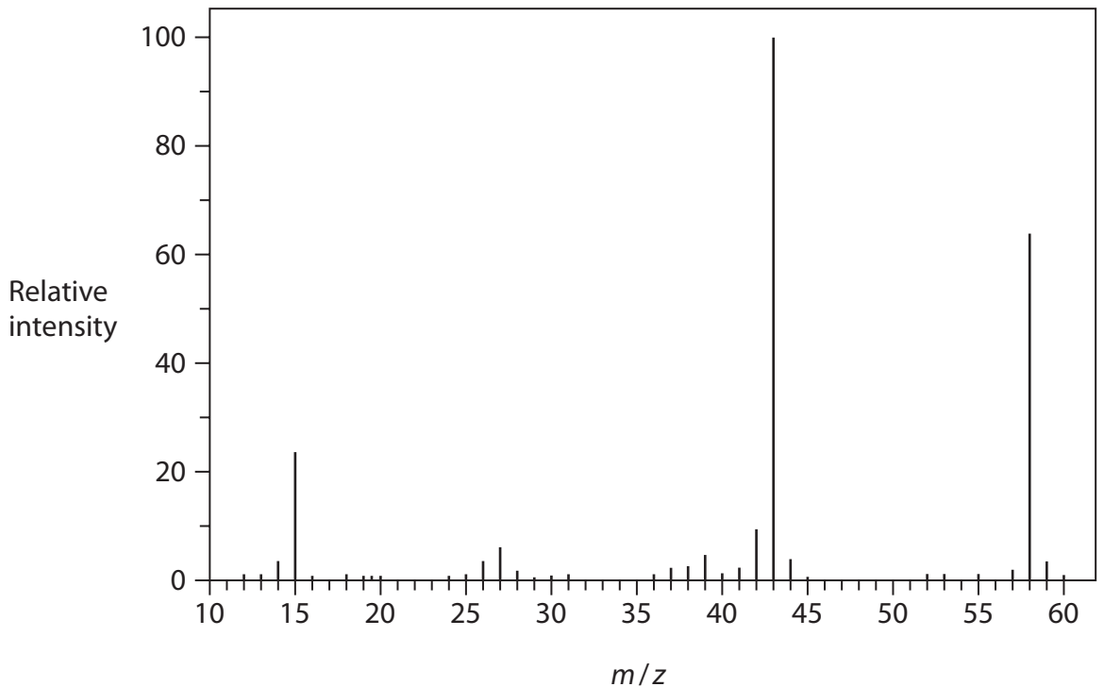


3-oxopentanedioic acid

- ☒ **A** 2
- ☒ **B** 3
- ☒ **C** 4
- ☒ **D** 5

(Total for Question 19 = 1 mark)

20 Which compound gives this mass spectrum?



- ☒ **A** CH_3COOH
- ☒ **B** CH_3COCH_3
- ☒ **C** CH_3CH_2CHO
- ☒ **D** $CH_3CH_2CH_2CH_3$

(Total for Question 20 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

BLANK PAGE

SECTION B

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

21 This question is about the element calcium and some of its compounds.

(a) Give the complete electronic configuration, using s, p, d notation, of a calcium atom in the ground state.

(1)

.....

(b) Calcium reacts with chlorine to form calcium chloride.

$$Ca(s) + Cl_2(g) \rightarrow CaCl_2(s)$$

(i) Explain, in terms of oxidation numbers, why this is a redox reaction.

(2)

.....

.....

.....

.....

.....

.....

(ii) Complete the table to indicate the type(s) of bonding and structure in the species involved in this reaction.

(3)

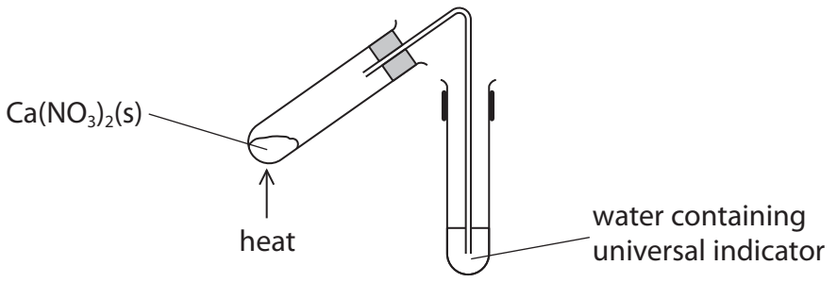
Species	Bonding	Structure
Ca(s)		
	covalent	
		giant

(iii) State the expected flame colour when $CaCl_2$ is used in a flame test.

(1)

.....

(c) A sample of solid anhydrous calcium nitrate, $Ca(NO_3)_2(s)$, is heated strongly for several minutes in the apparatus shown.



(i) State **two** observations that would be made.

(2)

1 .....

.....

2 .....

.....

(ii) Explain why the observations from (c)(i) would be made more quickly if the experiment was repeated with solid anhydrous magnesium nitrate, $Mg(NO_3)_2(s)$.

(3)

.....

.....

.....

.....

.....

.....

*(d) Samples of calcium and magnesium are added to separate test tubes of cold water containing a few drops of universal indicator.

State and explain the differences in the observations made in each experiment.

Include an equation in your answer.

(6)

(Total for Question 21 = 18 marks)

22 This question is about enthalpy changes.

A student wanted to use Hess's Law to determine the enthalpy change, $\Delta_r H_1$, in kJ mol^{-1}, for Reaction **1**.

Reaction **1** $Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$ $\Delta_r H_1$

(a) Explain why $\Delta_r H_1$ can also be described as an enthalpy change of formation.

(2)

.....

.....

.....

(b) The student carried out an experiment to determine the enthalpy change of reaction, $\Delta_r H_2$, in kJ mol^{-1}, for Reaction **2**.

Reaction **2** $MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$ $\Delta_r H_2$

0.189 g of solid magnesium oxide was added to excess hydrochloric acid in a polystyrene cup and stirred until the reaction was complete.

The total mass of the solution formed was 25.0 g.

During the experiment, the temperature increased from 21.5°C to 28.0°C.

Calculate $\Delta_r H_2$, in kJ mol^{-1}, including a sign.

Give your answer to an appropriate number of significant figures.

[Specific heat capacity of the solution = 4.18 J g^{-1} °C^{-1}.]

(4)

(c) Calculate the enthalpy change of reaction, $\Delta_r H_1$, for Reaction **1**.
Use your answer to (b), the data provided and the enthalpy cycle shown.

[If you did not calculate an answer to (b), use a value of $-100\,kJ\,mol^{-1}$.
This is **not** the correct answer.]

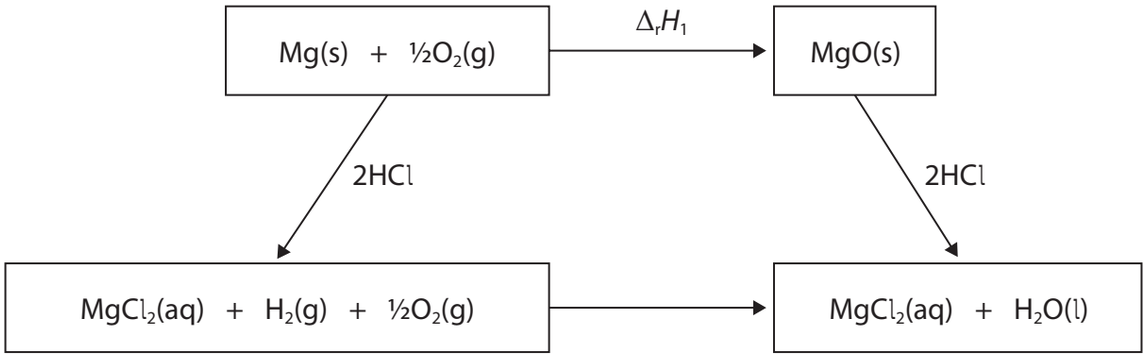
(2)

Data

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ $\quad \Delta_r H = -462\,kJ\,mol^{-1}$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta_f H = -286\,kJ\,mol^{-1}$

Enthalpy cycle



(Total for Question 22 = 8 marks)

BLANK PAGE

23 This question is about bromoalkanes with the molecular formula C_4H_9Br.

(a) (i) Give the IUPAC name of the only C_4H_9Br tertiary bromoalkane.

(1)

.....

(ii) Draw the **displayed** formula of the only C_4H_9Br secondary bromoalkane.

(1)

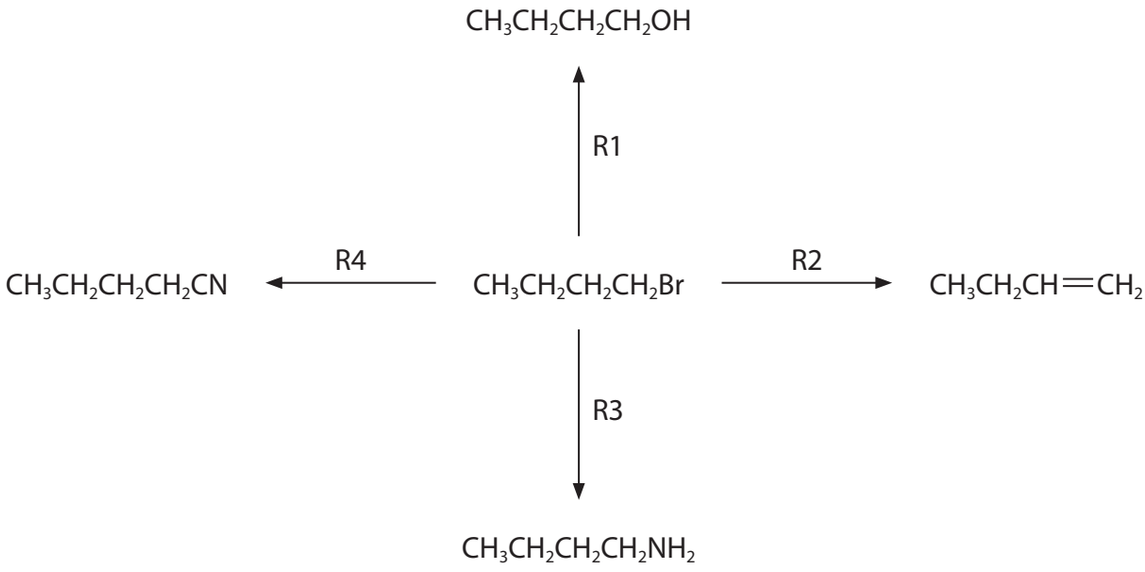
(iii) Draw the **skeletal** formula of the only branched-chain C_4H_9Br primary bromoalkane.

(1)

(b) Give the structure of the C_4H_9Br bromoalkane that would react fastest with aqueous silver nitrate in ethanol.

(1)

(c) Some reactions of $CH_3CH_2CH_2CH_2Br$ are shown.



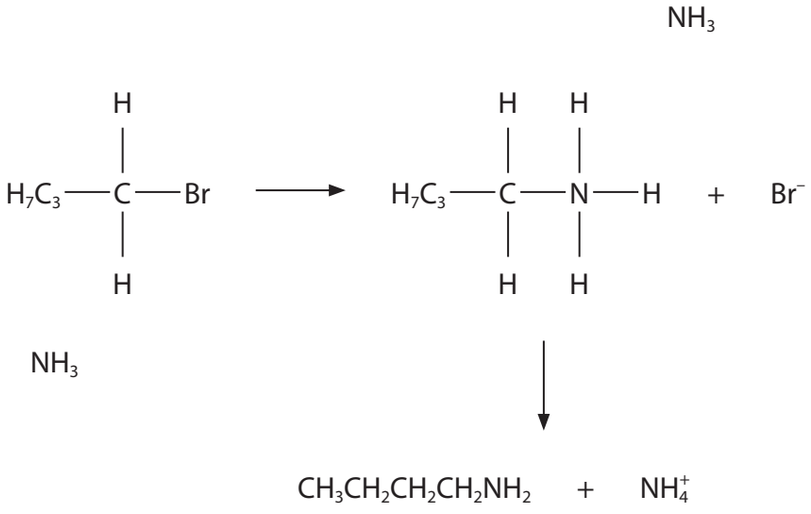
(i) Complete the table.

(4)

Reaction	Name of mechanism	Formula of reagent	Condition(s)
R1	nucleophilic substitution		
R2			heat in ethanol
R3		NH_3	
R4			heat in ethanol

(ii) Complete the mechanism for reaction R3.
Include curly arrows, and any relevant lone pairs, dipoles and charges.

(4)



(iii) Give the wavenumber range of an absorption in the infrared spectrum of the organic product of reaction R4, which is **not** present in the infrared spectrum of $CH_3CH_2CH_2CH_2Br$.
Indicate the bond responsible for this absorption.

(2)

Wavenumber range .....

Bond .....

(Total for Question 23 = 14 marks)

TOTAL FOR SECTION B = 40 MARKS

SECTION C

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

24 The elements of Group 7, the halogens, have many important uses.

Fluorine is used to make sulfur hexafluoride, SF_6, a gas which is used as an insulator in electrical equipment.

Chlorine is used as a bleach and as a disinfectant in water treatment.

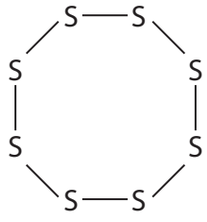
Bromine is used to make organic chemicals that are used as fire retardants.

Iodine has been used in the catalyst in the manufacture of ethanoic acid.

(a) SF_6 can be made from the reaction of sulfur, S_8, with fluorine.

$$S_8(s) + 24F_2(g) \rightarrow 8SF_6(g) \qquad \Delta_r H = -9672\,kJ\,mol^{-1}$$

The structure of $S_8(s)$ is shown.



Bond enthalpy data

Bond	Mean bond enthalpy / kJ mol^{-1}
S—S	268
F—F	151

(i) Calculate the mean bond enthalpy, in kJ mol^{-1}, for a single S—F bond.

(3)

(ii) Give **two** reasons why your answer to (a)(i) is unlikely to accurately represent the true S—F bond enthalpy in SF_6.

(2)

.....

.....

.....

.....

.....

.....

(iii) SF_6 is a potent greenhouse gas.

1.00 g of SF_6 absorbs the same amount of infrared radiation as 23.9 kg of CO_2.

Calculate the number of molecules of CO_2, to the nearest whole number, that absorb the same amount of infrared radiation as one molecule of SF_6 in the atmosphere.

(3)

(b) Bleach, NaClO(aq), is formed by the reaction of chlorine with cold, dilute aqueous sodium hydroxide.

$$Cl_2(g) + 2NaOH(aq) \rightarrow NaClO(aq) + NaCl(aq) + H_2O(l)$$

The following species and equilibria are present in solutions of NaClO(aq).

Equilibrium **1** $HClO(aq) \rightleftharpoons H^+(aq) + ClO^-(aq)$

Equilibrium **2** $HClO(aq) + Cl^-(aq) + H^+(aq) \rightleftharpoons Cl_2(aq) + H_2O(l)$

Equilibrium **3** $Cl_2(aq) \rightleftharpoons Cl_2(g)$

Household bleach is stored at a pH between 11 and 13.
Household bleach should not be stored near strong acid.

(i) Give the formula of the chlorine-containing species present at highest concentration in household bleach at pH 12.

(1)

.....

(ii) Explain why mixing strong acid with bleach is dangerous. Justify your answer using the equilibria shown.

(3)

.....

.....

.....

.....

.....

.....

.....

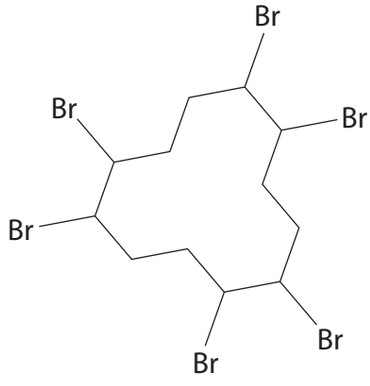
.....

(iii) On heating, NaClO disproportionates to form sodium chloride and sodium chlorate(V).

Give the equation for this disproportionation reaction.
State symbols are **not** required.

(2)

(c) The structure of a fire retardant is shown.



Calculate the percentage by mass of bromine in this fire retardant.
Give your answer to an appropriate number of significant figures.

(2)

(d) The industrial manufacture of ethanoic acid first used an iodine-based catalyst.

Explain, with the aid of a labelled Maxwell–Boltzmann distribution, how a catalyst increases the rate of a chemical reaction.

(4)

(Total for Question 24 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 80 MARKS

BLANK PAGE

BLANK PAGE

BLANK PAGE

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)											(13)	(14)	(15)	(16)	(17)	
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	(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							

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

Elements with atomic numbers 112-116 have been reported but not fully authenticated

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

* Lanthanide series

* Actinide series