

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 ►

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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 Which compound has intermolecular hydrogen bonding?

- ☐ A HF
- ☐ B H₂Te
- ☐ C AsH₃
- ☐ D SnH₄

(Total for Question 1 = 1 mark)

2 In which process are intermolecular hydrogen bonds broken?

- ☐ A H₂(g) → 2H(g)
- ☐ B H₂O(l) → H₂O(g)
- ☐ C H₂(l) → H₂(g)
- ☐ D H₂(g) + ½O₂(g) → H₂O(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 BeCl₂
- ☐ C PH₃
- ☐ D Cl₄

(Total for Question 3 = 1 mark)



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

- ☐ A $(\text{CH}_3)_4\text{C}$
- ☐ B $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
- ☐ C $(\text{C}_2\text{H}_5)_4\text{C}$
- ☐ D $\text{CH}_3(\text{CH}_2)_7\text{CH}_3$

(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 $\text{Br}_2 + \text{F}_2 \rightarrow 2\text{BrF}$
- ☐ B $\text{U} + 3\text{ClF}_3 \rightarrow \text{UF}_6 + 3\text{ClF}$
- ☐ C $2\text{F}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{HF} + \text{O}_2$
- ☐ D $\text{KCl} + \text{H}_2\text{SO}_4 \rightarrow \text{HCl} + \text{KHSO}_4$

(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

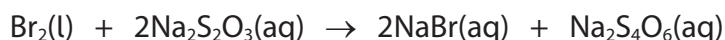
(Total for Question 8 = 1 mark)

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, $\text{Br}_2(\text{l})$, can be disposed of safely by reaction with aqueous sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$.



What is the minimum volume, in cm^3 , of 0.5 mol dm^{-3} $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ needed to react completely with 0.01 mol of $\text{Br}_2(\text{l})$?

- ☐ A 0.01
- ☐ B 0.04
- ☐ C 10
- ☐ D 40

(Total for Question 10 = 1 mark)

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11 What is the mass of nitrogen **atoms** in 50 cm^3 of a 2.0 mol dm^{-3} solution of ammonium nitrate, $\text{NH}_4\text{NO}_3(\text{aq})$?

- ☐ 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 $E \geq E_a$ 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 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 6\text{O}_2 \rightarrow 4\text{CO}_2 + 5\text{H}_2\text{O}$
- ☐ B $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 6\frac{1}{2}\text{O}_2 \rightarrow 4\text{CO}_2 + 5\text{H}_2\text{O}$
- ☐ C $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 4\text{O}_2 \rightarrow 4\text{CO} + 5\text{H}_2\text{O}$
- ☐ D $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 4\frac{1}{2}\text{O}_2 \rightarrow 4\text{CO} + 5\text{H}_2\text{O}$

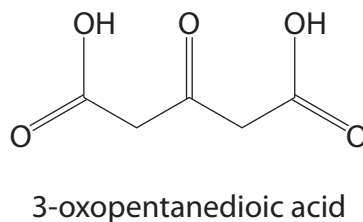
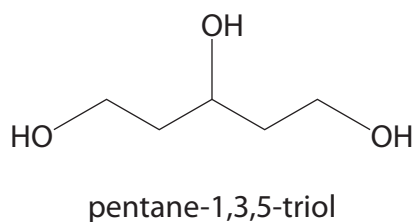
(Total for Question 17 = 1 mark)

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 $[\text{O}]$ is needed to convert 1 mol of pentane-1,3,5-triol into 3-oxopentanedioic acid and water?

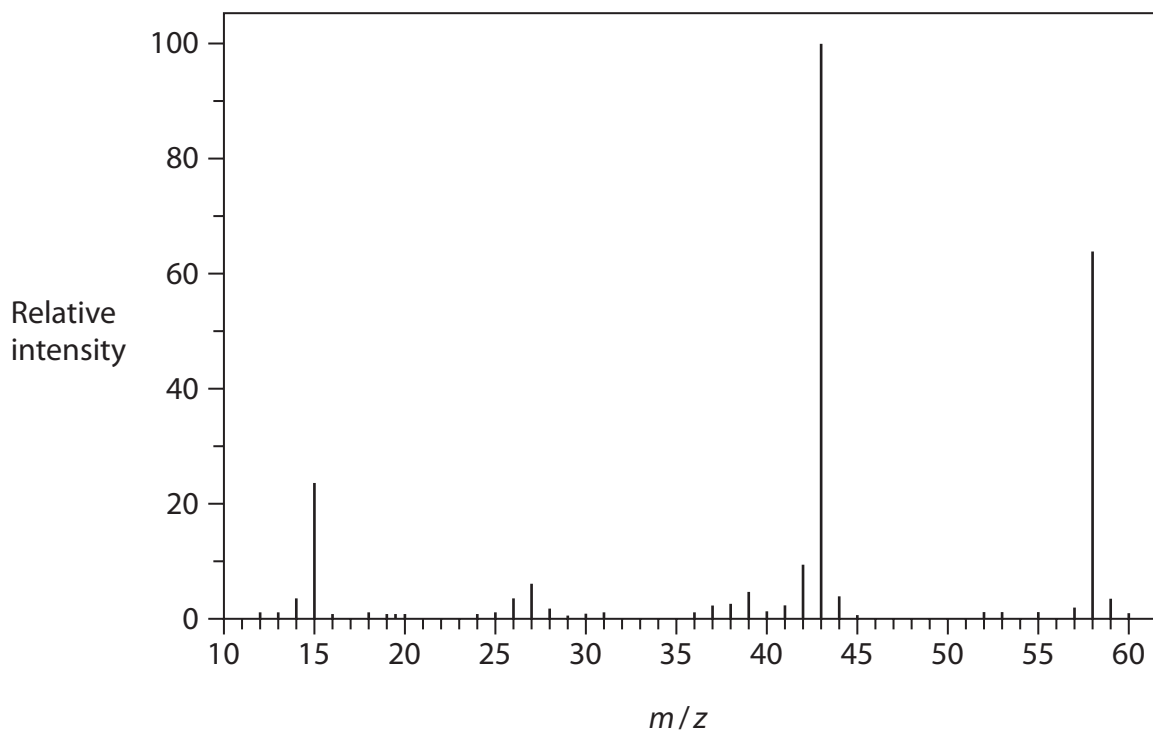


- ☐ A 2
- ☐ B 3
- ☐ C 4
- ☐ D 5

(Total for Question 19 = 1 mark)



20 Which compound gives this mass spectrum?



- ☐ A CH_3COOH
- ☐ B CH_3COCH_3
- ☐ C $\text{CH}_3\text{CH}_2\text{CHO}$
- ☐ D $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$

(Total for Question 20 = 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.

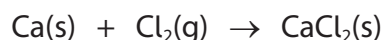
21 This question is about the element calcium and some of its compounds.

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

(1)

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



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

(2)

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- (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 CaCl₂ is used in a flame test.

(1)

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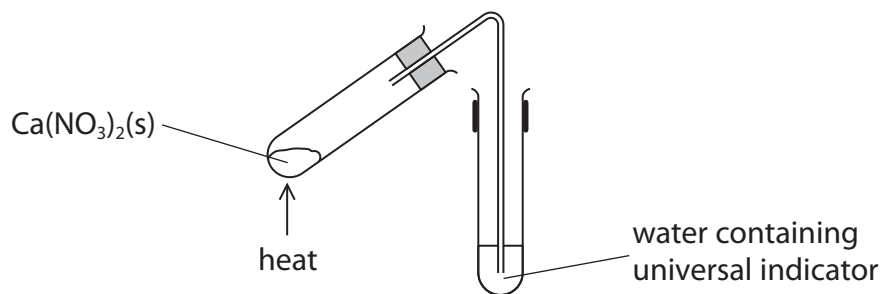
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- (c) A sample of solid anhydrous calcium nitrate, $\text{Ca}(\text{NO}_3)_2(\text{s})$, is heated strongly for several minutes in the apparatus shown.



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

(2)

1

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2

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- (ii) Explain why the observations from (c)(i) would be made more quickly if the experiment was repeated with solid anhydrous magnesium nitrate, $\text{Mg}(\text{NO}_3)_2(\text{s})$.

(3)

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*(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)



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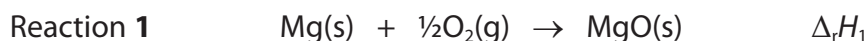
Handwriting practice area with 20 horizontal dotted lines.

(Total for Question 21 = 18 marks)



22 This question is about enthalpy changes.

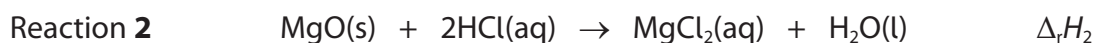
A student wanted to use Hess's Law to determine the enthalpy change, $\Delta_r H_1$, in kJ mol^{-1} , for Reaction 1.



(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.



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 = $4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$.]

(4)

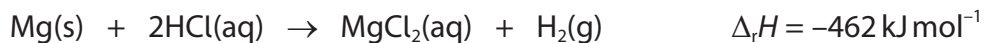


- (c) Calculate the enthalpy change of reaction, $\Delta_r H_1$, for Reaction 1.
Use your answer to (b), the data provided and the enthalpy cycle shown.

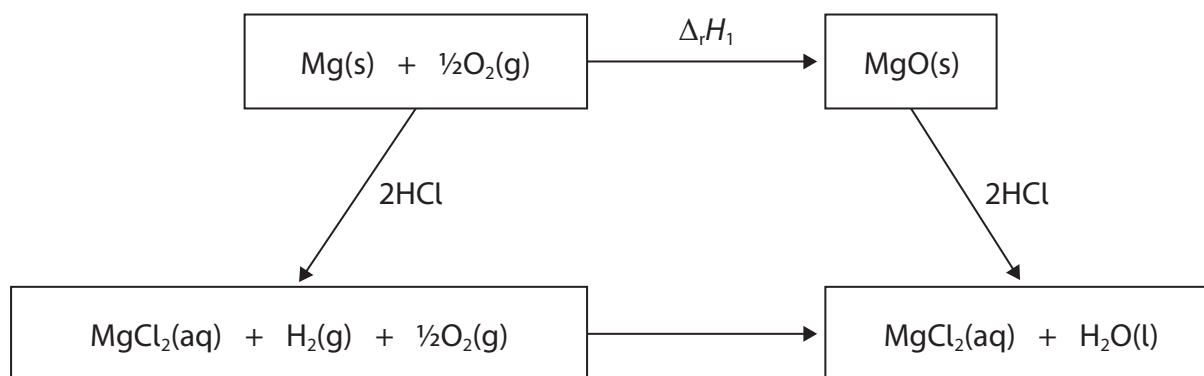
[If you did not calculate an answer to (b), use a value of -100 kJ mol^{-1} .
This is **not** the correct answer.]

(2)

Data



Enthalpy cycle



(Total for Question 22 = 8 marks)

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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.

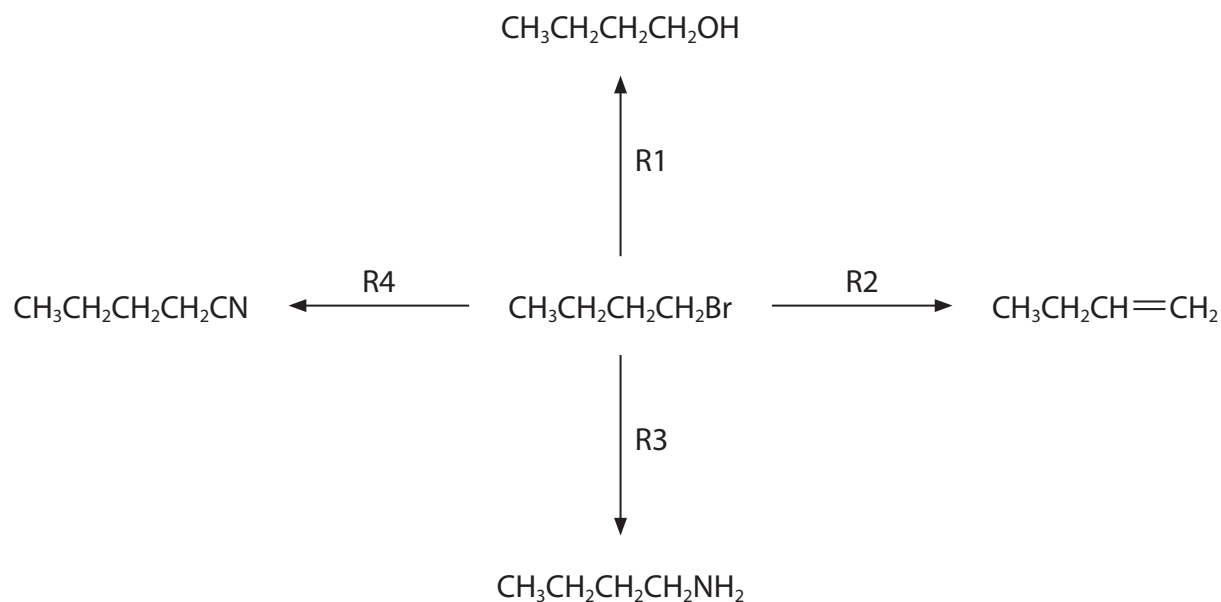
(1)

(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 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$ are shown.



(i) Complete the table.

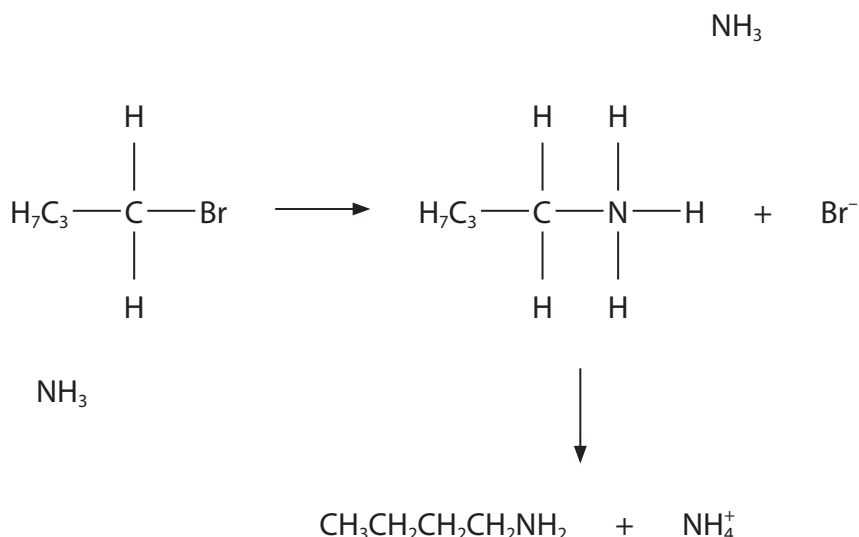
(4)

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 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$.
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.

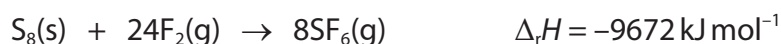
Fluorine is used to make sulfur hexafluoride, SF_6 , a gas which is used as an insulator in electrical equipment.

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

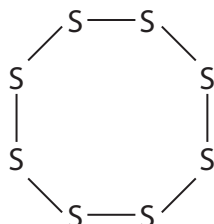
Bromine is used to make organic chemicals that are used as fire retardants.

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.



The structure of $\text{S}_8(\text{s})$ is shown.



Bond enthalpy data

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

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

(3)



- (ii) Give **two** reasons why your answer to (a)(i) is unlikely to accurately represent the true S—F bond enthalpy in SF₆.

(2)

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- (iii) SF₆ is a potent greenhouse gas.

1.00 g of SF₆ absorbs the same amount of infrared radiation as 23.9 kg of CO₂.

Calculate the number of molecules of CO₂, to the nearest whole number, that absorb the same amount of infrared radiation as one molecule of SF₆ in the atmosphere.

(3)

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



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



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)

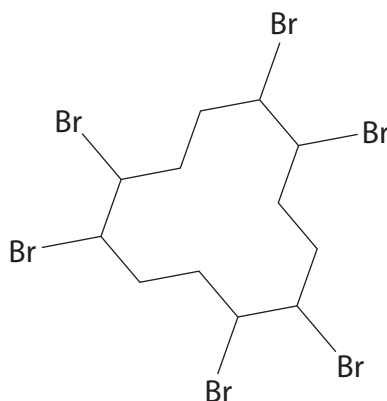


- (iii) On heating, NaClO disproportionates to form sodium chloride and sodium chlorate(V).

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)

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(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



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The Periodic Table of Elements

1	2	3	4	5	6	7	0 (8)
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	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	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	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	200.6 Hg mercury 80	201.0 Tl thallium 81	204.4 Pb lead 82	207.2 Bi bismuth 83	209.0 Po polonium 84	210.0 At astatine 85
Elements with atomic numbers 112-116 have been reported but not fully authenticated							
140 Ce cerium 58	141 Pr praseodymium 59	142 Nd neodymium 60	143 Pm promethium 61	144 Sm samarium 62	145 Eu europium 63	146 Gd gadolinium 64	147 Tb terbium 65
148 Dy dysprosium 66	149 Ho holmium 67	150 Er erbium 68	151 Tm thulium 69	152 Yb ytterbium 70	153 Lu lutetium 71	154 Hf hafnium 72	155 Ta tantalum 73
157 W tungsten 74	158 Re rhenium 75	159 Os osmium 76	160 Ir iridium 77	161 Pt platinum 78	162 Au gold 79	163 Hg mercury 80	164 Tl thallium 81
166 Pb lead 82	167 Bi bismuth 83	168 Po polonium 84	169 At astatine 85	170 Rn radon 86	171 Fr francium 87	172 Ra radium 88	173 Ac actinium 89
174 Th thorium 90	175 Pa protactinium 91	176 U uranium 92	177 Np neptunium 93	178 Pu plutonium 94	179 Am americium 95	180 Cm curium 96	181 Bk berkelium 97
182 Cf californium 98	183 Es einsteinium 99	184 Fm fermium 100	185 Md mendelevium 101	186 No nobelium 102	187 Lr lawrencium 103	188 Rf rutherfordium 104	189 Db dubnium 105
190 Sg seaborgium 106	191 Bh bohrium 107	192 Hs hassium 108	193 Mt meitnerium 109	194 Ds darmstadtium 110	195 Rg roentgenium 111	196 Uu ununium 112	197 Uub ununbium 113
198 Uut ununium 114	199 Uuq ununium 115	200 Uuh ununium 116	201 Uus ununium 117	202 Uuo ununium 118	203 Uuq ununium 119	204 Uuh ununium 120	205 Uus ununium 121
206 Uuo ununium 122	207 Uus ununium 123	208 Uuo ununium 124	209 Uus ununium 125	210 Uuo ununium 126	211 Uus ununium 127	212 Uuo ununium 128	213 Uus ununium 129
214 Uuo ununium 130	215 Uus ununium 131	216 Uuo ununium 132	217 Uus ununium 133	218 Uuo ununium 134	219 Uus ununium 135	220 Uuo ununium 136	221 Uus ununium 137
222 Uuo ununium 138	223 Uus ununium 139	224 Uuo ununium 140	225 Uus ununium 141	226 Uuo ununium 142	227 Uus ununium 143	228 Uuo ununium 144	229 Uus ununium 145
230 Uuo ununium 146	231 Uus ununium 147	232 Uuo ununium 148	233 Uus ununium 149	234 Uuo ununium 150	235 Uus ununium 151	236 Uuo ununium 152	237 Uus ununium 153
238 Uuo ununium 154	239 Uus ununium 155	240 Uuo ununium 156	241 Uus ununium 157	242 Uuo ununium 158	243 Uus ununium 159	244 Uuo ununium 160	245 Uus ununium 161
246 Uuo ununium 162	247 Uus ununium 163	248 Uuo ununium 164	249 Uus ununium 165	250 Uuo ununium 166	251 Uus ununium 167	252 Uuo ununium 168	253 Uus ununium 169
254 Uuo ununium 170	255 Uus ununium 171	256 Uuo ununium 172	257 Uus ununium 173	258 Uuo ununium 174	259 Uus ununium 175	260 Uuo ununium 176	261 Uus ununium 177
262 Uuo ununium 178	263 Uus ununium 179	264 Uuo ununium 180	265 Uus ununium 181	266 Uuo ununium 182	267 Uus ununium 183	268 Uuo ununium 184	269 Uus ununium 185
270 Uuo ununium 186	271 Uus ununium 187	272 Uuo ununium 188	273 Uus ununium 189	274 Uuo ununium 190	275 Uus ununium 191	276 Uuo ununium 192	277 Uus ununium 193
278 Uuo ununium 194	279 Uus ununium 195	280 Uuo ununium 196	281 Uus ununium 197	282 Uuo ununium 198	283 Uus ununium 199	284 Uuo ununium 200	285 Uus ununium 201
286 Uuo ununium 202	287 Uus ununium 203	288 Uuo ununium 204	289 Uus ununium 205	290 Uuo ununium 206	291 Uus ununium 207	292 Uuo ununium 208	293 Uus ununium 209
294 Uuo ununium 210	295 Uus ununium 211	296 Uuo ununium 212	297 Uus ununium 213	298 Uuo ununium 214	299 Uus ununium 215	300 Uuo ununium 216	301 Uus ununium 217
302 Uuo ununium 218	303 Uus ununium 219	304 Uuo ununium 220	305 Uus ununium 221	306 Uuo ununium 222	307 Uus ununium 223	308 Uuo ununium 224	309 Uus ununium 225
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542 Uuo ununium 458	543 Uus ununium 459	544 Uuo ununium 460	545 Uus ununium 461	546 Uuo ununium 462	547 Uus ununium 463	548 Uuo ununium 464	549 Uus ununium 465
550 Uuo ununium 466	551 Uus ununium 467</						