Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Monday 13 October 2025

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, 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 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.
- Show all your working in calculations and include units where appropriate.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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P 7 8 8 2 8 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 What colour is the solution that forms when iodine dissolves in a hydrocarbon solvent?

☒ **A** brown

☒ **B** grey

☒ **C** purple

☒ **D** yellow

(Total for Question 1 = 1 mark)

2 Which row shows the correct trends **down** Group 2?

	Reactivity of element	Solubility of hydroxides	Solubility of sulfates
☒ **A**	increases	increases	decreases
☒ **B**	increases	decreases	increases
☒ **C**	decreases	increases	decreases
☒ **D**	decreases	decreases	increases

(Total for Question 2 = 1 mark)

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

3 The gas nitrogen dioxide, NO_2, exists in equilibrium with another gas, dinitrogen tetroxide, N_2O_4.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

brown colourless

What happens to the colour of the equilibrium mixture when a catalyst is added?

- ☒ **A** becomes darker
- ☒ **B** becomes paler
- ☒ **C** becomes darker, then becomes paler
- ☒ **D** no change

(Total for Question 3 = 1 mark)

4 Which isomer has the **lowest** boiling temperature?

- ☒ **A** 2,3-dimethylpentane
- ☒ **B** 3,3-dimethylpentane
- ☒ **C** 2,2,3-trimethylbutane
- ☒ **D** heptane

(Total for Question 4 = 1 mark)

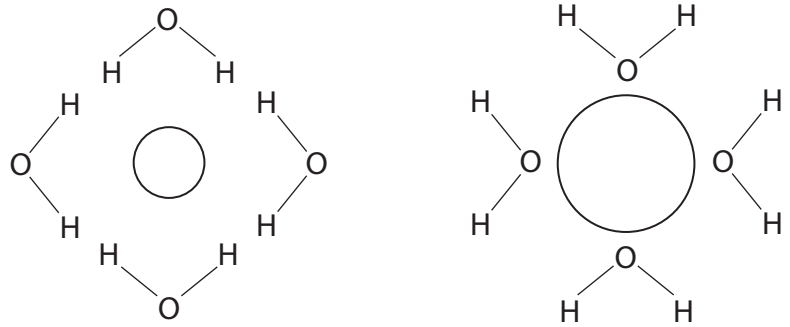
Use this space for any rough working. Anything you write in this space will gain no credit.

5 Sodium chloride dissolves in water.

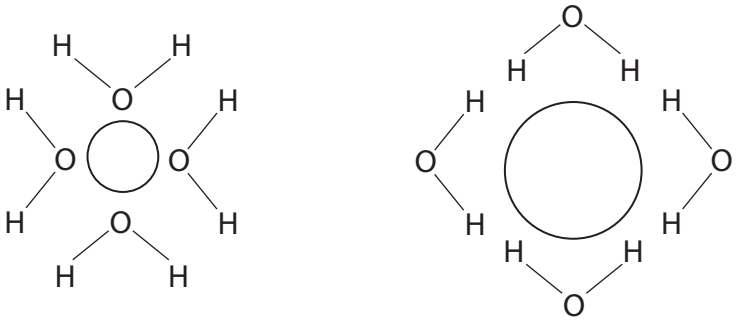
(a) Which diagram shows the arrangement of water molecules around a sodium ion and a chloride ion in solution?

(1)

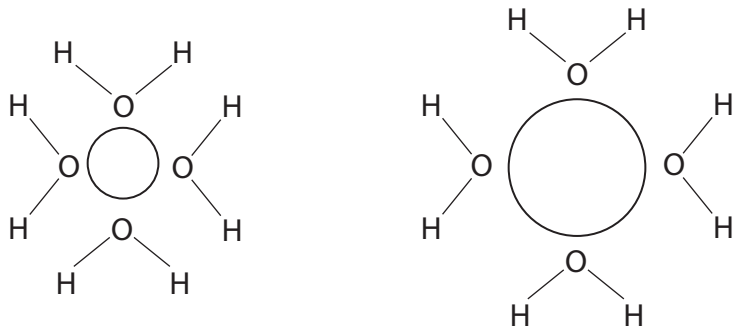
☒ **A**



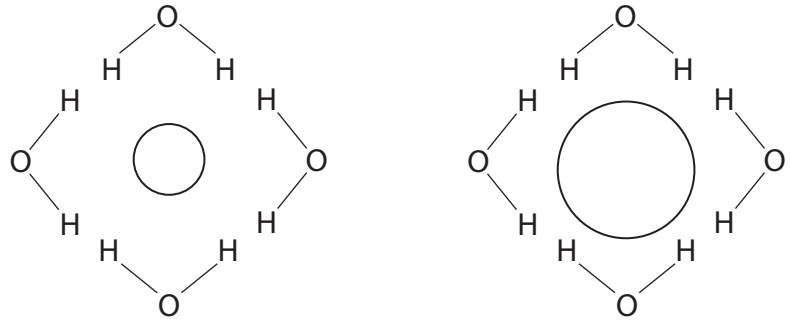
☒ **B**



☒ **C**



☒ **D**



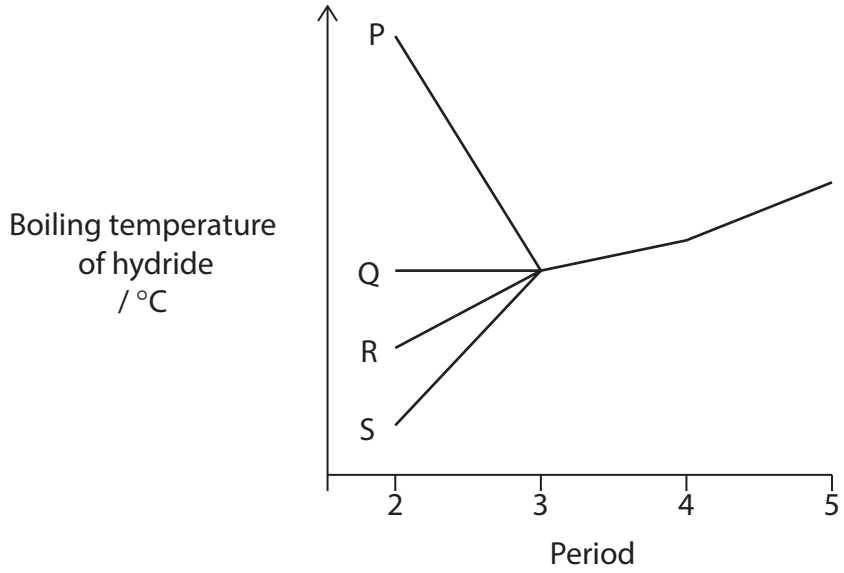
(b) What is the name of the attraction between water molecules and the sodium ions and chloride ions?

(1)

- ☒ **A** instantaneous dipole–induced dipole
- ☒ **B** permanent dipole–permanent dipole
- ☒ **C** hydrogen bonds
- ☒ **D** ion–permanent dipole

(Total for Question 5 = 2 marks)

6 Which line on the sketch graph best shows the trend in boiling temperature for the hydrides of elements in Group 6?



- ☒ **A** P
- ☒ **B** Q
- ☒ **C** R
- ☒ **D** S

(Total for Question 6 = 1 mark)

7 A mixture contains 36 g of water and 46 g of ethanol.

What is the approximate percentage of water in the mixture by **moles**?

- ☒ **A** 67%
- ☒ **B** 56%
- ☒ **C** 44%
- ☒ **D** 33%

(Total for Question 7 = 1 mark)

8 Hydrogen peroxide decomposes as shown.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

20 cm^3 of 2.00 mol dm^{-3} hydrogen peroxide solution completely decomposes at room temperature and pressure (r.t.p.).

What volume of oxygen is produced?

[Data: Molar volume of an ideal gas at r.t.p. = 24.0 dm^3 mol^{-1}]

☒ **A** 1.92 dm^3

☒ **B** 0.96 dm^3

☒ **C** 0.48 dm^3

☒ **D** 0.24 dm^3

(Total for Question 8 = 1 mark)

9 But-1-ene burns in oxygen as shown, in a closed system.

$$C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(l)$$

What volume of gas remains in the system when 20 cm^3 of but-1-ene burns completely in 200 cm^3 of oxygen?

Assume all volumes are measured at r.t.p.

☒ **A** 80 cm^3

☒ **B** 160 cm^3

☒ **C** 240 cm^3

☒ **D** 280 cm^3

(Total for Question 9 = 1 mark)

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

10 Ethanol can be oxidised by acidified dichromate ions as shown.

$$3C_2H_5OH + 16H^+ + 2Cr_2O_7^{2-} \rightarrow 3CH_3COOH + 4Cr^{3+} + 11H_2O$$

(a) What is the change in oxidation number for **each** chromium atom?

(1)

☒ **A** decrease by 12

☒ **B** decrease by 6

☒ **C** decrease by 3

☒ **D** increase by 5

(b) 23 g of ethanol is oxidised by a solution of 0.100 mol dm^{-3} $Cr_2O_7^{2-}$ ions.

Which expression shows the **minimum** volume, in dm^3, of this solution needed to oxidise all the ethanol as shown in the equation?

(1)

☒ **A** $0.5 \times \frac{3}{2} \times 10$

☒ **B** $0.5 \times \frac{2}{3} \times 10$

☒ **C** $0.5 \times \frac{3}{2} \div 10$

☒ **D** $0.5 \times \frac{2}{3} \div 10$

(Total for Question 10 = 2 marks)

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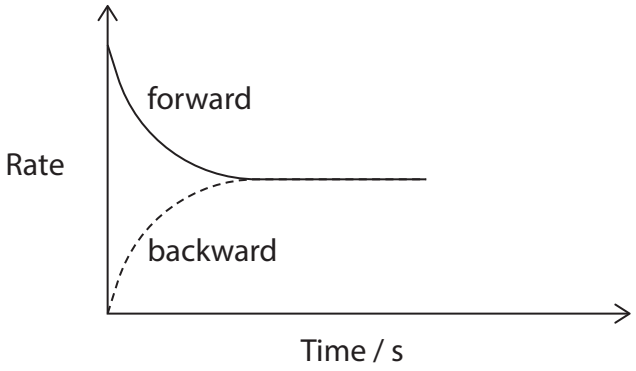
11 A student studies a graph of rate against time for both forward and backward reactions in a reversible reaction.



The student makes these statements.

1. the reaction reaches equilibrium
2. the forward reaction is fast initially because the concentration of reactants is at its highest
3. the rate of both the reactions at equilibrium is 0.00 mol dm^{-3} s^{-1}

How many of the statements made by the student are correct?

☒ **A** three of the statements

☒ **B** two of the statements

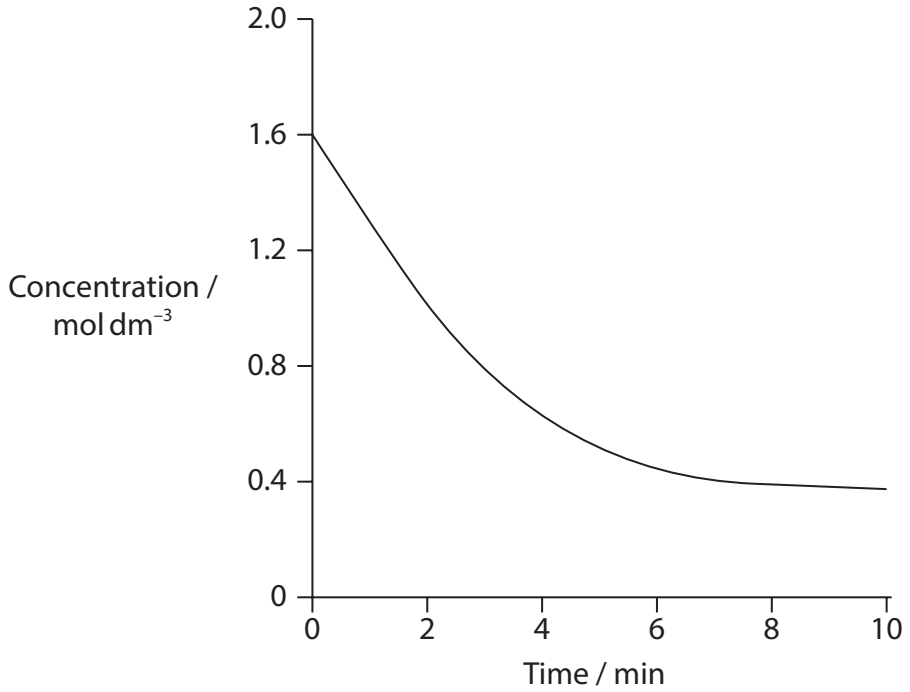
☒ **C** one of the statements

☒ **D** none of the statements

(Total for Question 11 = 1 mark)

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

12 The graph shows the change in concentration against time for a reaction.



What is the best **estimate** for the value of the rate, in mol dm^{-3} min^{-1}, at 4 minutes?

- ☒ **A** 8.00
- ☒ **B** 2.50
- ☒ **C** 0.40
- ☒ **D** 0.15

(Total for Question 12 = 1 mark)

13 Which test would **not** enable a chemistry student to distinguish between ethanol and ethanal?

- ☒ **A** adding a very small piece of sodium metal to each liquid
- ☒ **B** adding sodium carbonate solution to each liquid
- ☒ **C** warming each liquid with Fehling's solution
- ☒ **D** adding PCl_5 to each liquid

(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 of the statements about C═O bonds, found in aldehydes and ketones, are correct?

1 the C═O bond is shorter than a C—O bond

2. the C═O bond consists of two π-bonds

3. the C═O bond consists of four shared electrons

☒ **A** statements 1 and 2

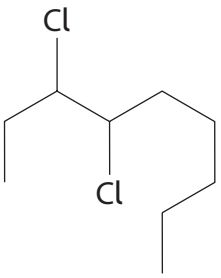
☒ **B** statements 1 and 3

☒ **C** statements 2 and 3

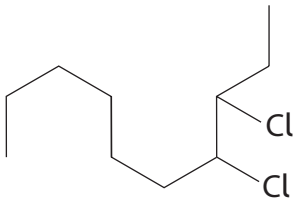
☒ **D** statements 1, 2 and 3

(Total for Question 14 = 1 mark)

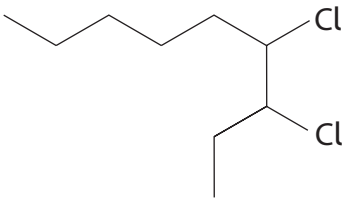
15 Which statement about these structures is correct?



Structure 1



Structure 2



Structure 3

☒ **A** all three structures show the same compound

☒ **B** structures 2 and 3 show the same compound

☒ **C** structures 1 and 3 show the same compound

☒ **D** all three structures show different compounds

(Total for Question 15 = 1 mark)

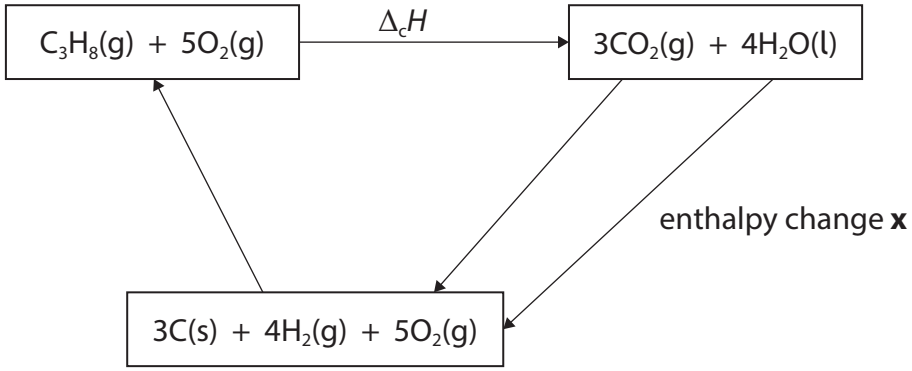
Use this space for any rough working. Anything you write in this space will gain no credit.

16 Which reaction has a standard enthalpy change equal to the standard enthalpy change of formation of strontium fluoride?

- ☒ **A** $Sr^{2+}(s) + 2F^-(g) \rightarrow SrF_2(s)$
- ☒ **B** $Sr^{2+}(g) + 2F^-(g) \rightarrow SrF_2(s)$
- ☒ **C** $Sr(s) + F_2(g) \rightarrow SrF_2(s)$
- ☒ **D** $Sr(g) + F_2(g) \rightarrow SrF_2(s)$

(Total for Question 16 = 1 mark)

17 A Hess cycle is shown which could be used to calculate the enthalpy change of combustion of propane, $\Delta_c H$.



Which expression is equal to the enthalpy change **x**, shown on the diagram?

- ☒ **A** $-1 \times \Delta_f H^{\ominus}(H_2O(l))$
- ☒ **B** $1 \times \Delta_f H^{\ominus}(H_2O(l))$
- ☒ **C** $-4 \times \Delta_f H^{\ominus}(H_2O(l))$
- ☒ **D** $4 \times \Delta_f H^{\ominus}(H_2O(l))$

(Total for Question 17 = 1 mark)

18 Which compound will produce a mass spectrum with a major peak at $m/z = 31$?

- ☒ **A** propan-1-ol, $CH_3CH_2CH_2OH$
- ☒ **B** propan-2-ol, $CH_3CHOHCH_3$
- ☒ **C** propanal, CH_3CH_2CHO
- ☒ **D** propanone, CH_3COCH_3

(Total for Question 18 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

19 This question is about calcium and its compounds.

(a) A sample of calcium is burned in air, forming calcium oxide.

(i) Complete the equation for this reaction including state symbols.

(1)

.....Ca(.....) + O_2(.....) → .....CaO(.....)

(ii) State the flame colour seen during the reaction.

(1)

.....

(iii) Explain how a flame colour forms.

(3)

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(b) The calcium oxide formed is impure because during the reaction, calcium reacts with another element in air, forming a compound.

Give the formula of the compound.

(1)

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(c) Another sample of impure calcium oxide, made from heating limestone, has a mass of 5.12 g.
The impurities do not react with hydrochloric acid.

The sample is added to 200 cm^3 of 1.00 mol dm^{-3} hydrochloric acid, forming a solution. The hydrochloric acid is in excess.

$$CaO + 2HCl \rightarrow CaCl_2 + H_2O$$

The solution containing excess acid is transferred to a volumetric flask and made up to a volume of 250.0 cm^3 using deionised water and then mixed.

A 25.0 cm^3 sample of this diluted solution is titrated with 0.150 mol dm^{-3} sodium hydroxide solution.
The mean titre is 23.70 cm^3.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Calculate the percentage purity of the calcium oxide sample.

(6)

(d) Calcium nitrate is a white crystalline solid that decomposes when heated strongly with a Bunsen burner.

$$2Ca(NO_3)_2 \rightarrow 2CaO + 4NO_2 + O_2$$

A student suggested an explanation for this decomposition.

"The calcium ion is polarised by the nitrate ion. This distorts the electron cloud around the nitrate ion, and so weakens the bond between the two ions."

Identify **two** errors in this suggestion and include corrections that give an explanation of the decomposition.

(2)

Error 1

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.....

Correction

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Error 2

.....

.....

Correction

.....

.....

(Total for Question 19 = 14 marks)

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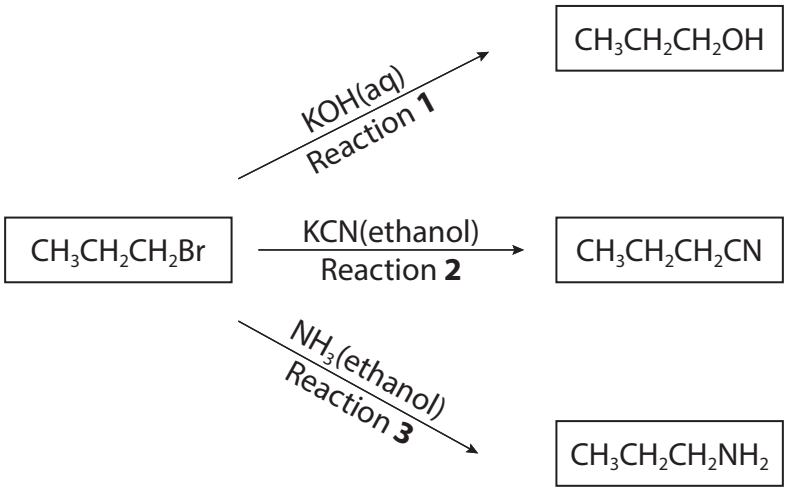
20 This question is about some reactions of the halogenoalkane, 1-bromopropane, $CH_3CH_2CH_2Br$.



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

(2)

(b) Give the reason why chemists often use Reaction **2**, the formation of a nitrile, when synthesising organic compounds.

(1)

.....

.....

(c) Give the conditions needed for Reaction **3**.

(1)

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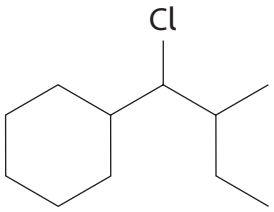
(d) A different type of reaction occurs when the halogenoalkane (1-chloro-2-methylbutyl)cyclohexane is heated with sodium hydroxide dissolved in ethanol.



(1-chloro-2-methylbutyl)cyclohexane

(i) Explain why anhydrous calcium chloride is added to ethanol before it is used to dissolve the sodium hydroxide.

(2)

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(ii) Draw the **skeletal formulae** of the three isomers formed in this reaction.

(3)

(Total for Question 20 = 9 marks)

21 This question is about Group 7 elements and their compounds.

(a) The compound $NaClO_3$ is used in the paper industry to bleach wood pulp.
It is made by the reaction of hot sodium hydroxide solution with chlorine gas.

$$6NaOH(aq) + 3Cl_2(g) \rightarrow 5NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$$

(i) Explain, in terms of oxidation numbers, what type of reaction occurs.

(3)

(ii) Calculate the percentage atom economy by mass for the formation of $NaClO_3$ in this reaction.

(2)

*(b) A student tests samples of the solids sodium chloride and sodium iodide with concentrated sulfuric acid.

The following observations are made.

Name of halide	Observations
sodium chloride	• misty fumes seen, which form a white smoke with $NH_3(g)$
sodium iodide	• misty fumes seen, which form a white smoke with $NH_3(g)$ • purple vapour • a smell of rotten eggs

Evaluate these observations to decide which halide ion is the stronger reducing agent.

Support your answer with

- the products formed, by referring to the observations
- the changes in oxidation number to justify your deduction of the stronger reducing agent
- an ionic equation for the reaction that produces a smell of rotten eggs. State symbols are not required.

(6)

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(Total for Question 21 = 11 marks)

22 The Sabatier process uses carbon dioxide and hydrogen to produce methane and water.

$$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(g) \qquad \Delta_r H = -165\,kJ\,mol^{-1}$$

The process is carried out at a temperature of 400 °C and a pressure of 30 atm, in the presence of a nickel catalyst.

(a) Discuss the advantages and disadvantages of using such high temperatures and pressures in the process.

(5)

(b) State how a catalyst increases the rate of a reaction.

(1)

(Total for Question 22 = 6 marks)

TOTAL FOR SECTION B = 40 MARKS

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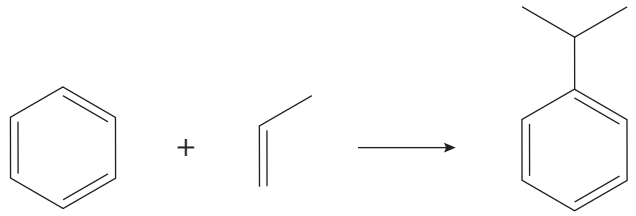
SECTION C

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

23 This question is about alcohols and related compounds.

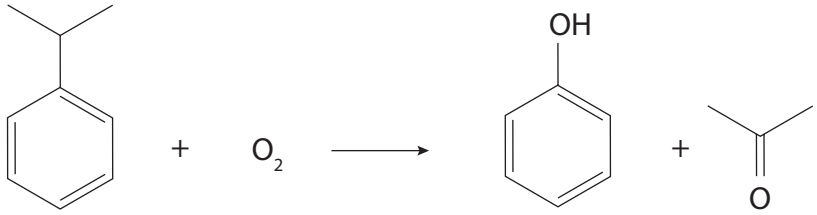
Propan-2-ol is a secondary alcohol. One of its uses is as a solvent to clean the surfaces of vinyl records.

Propan-2-ol can be oxidised to form the ketone, propanone, in a laboratory. However, most propanone produced in industry is made using the Cumene process, where hydrocarbons from oil are used to synthesise cumene.



benzene propene cumene

Cumene is then oxidised directly to form phenol and propanone.



cumene oxygen phenol propanone

Propan-1-ol is also a solvent, and can be used as a fuel. The fuel biopropanol, which is mainly propan-1-ol, is formed from glycerol, a waste product of biodiesel production from plant oils.

The reaction used is called hydrogenolysis, and requires catalysts containing nickel, tungsten and zirconium.

(a) State what is meant by the term 'secondary alcohol'.

(1)

.....

.....

.....

(b) The oxidising agent used to oxidise propan-2-ol in a laboratory is an acidified solution containing $Cr_2O_7^{2-}$ ions.

(i) The reaction mixture is placed in a pear-shaped flask and heated for 30 minutes.

Give the name of the additional piece of equipment needed when heating the reaction mixture for this length of time without any loss of the mixture.

(1)

.....

.....

(ii) Describe the colour change that occurs during this heating.

(1)

.....

(iii) Describe how the IR spectrum of the reaction mixture would change during this reaction.
Your answer should consider only the **organic** reactant and product.
Use information from the Data Booklet to support your answer.

(3)

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(c) The Cumene process is shown using molecular formulae.

Step **1**

$$C_6H_6 + C_3H_6 \rightarrow C_9H_{12}$$

benzene + propene → cumene

Step **2**

$$C_9H_{12} + O_2 \rightarrow C_6H_6O + C_3H_6O$$

cumene + oxygen → phenol + propanone

(i) Calculate the mass of benzene, in **kg**, needed to produce 2000 dm^3 of propanone using the Cumene process.
You should assume that the overall yield of the process is 85.0%.

[Data: Density of propanone = 0.784 g cm^{-3}]

(4)

(ii) Most chemists would say that Step **2** of the Cumene process has an overall percentage atom economy by mass of 100%, even though there are two products.

State what can be deduced from this comment.

(1)

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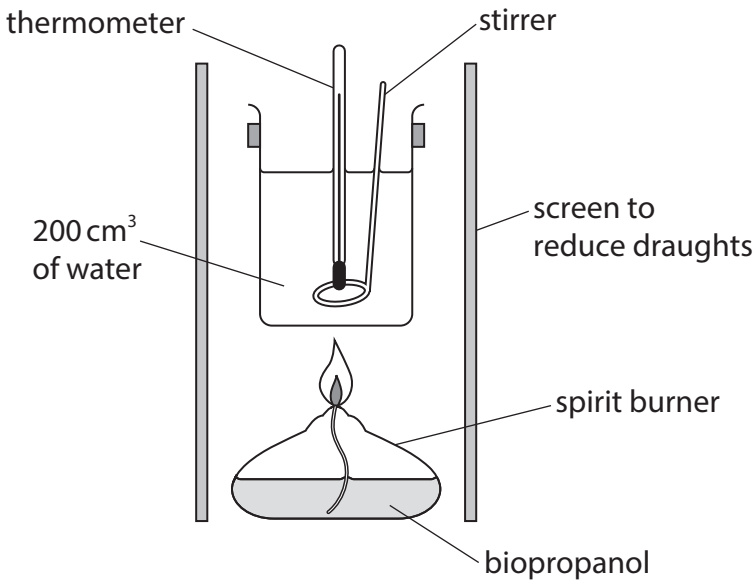
(d) Data about some physical properties of propan-2-ol and propanone are shown.

Compound	Boiling temperature / °C	Solubility in water
propan-2-ol	82.6	fully miscible
propanone	56.1	fully miscible

Compare and contrast these physical properties.
Justify your answer in terms of intermolecular forces.
Descriptions of how intermolecular forces form are not required.

(4)

(e) A copper calorimeter containing 200 cm^3 of water at 20°C is heated using a spirit burner containing biopropanol.



A mass of 1.02 g of biopropanol is burned during the experiment.

(i) Calculate the maximum temperature, in °C, of the water at the end of the experiment.
You should assume that there is complete combustion and that all energy produced is transferred to the water.

[Data: Specific heat capacity of water = 4.18 $J K^{-1} mol^{-1}$
$\Delta_c H^{\ominus}$(biopropanol) = –2021 $kJ mol^{-1}$]

(4)

(ii) Biopropanol has a higher octane number than bioethanol.

Name the process carried out on alkanes obtained from crude oil to increase the octane number of a fuel.

(1)

.....

(Total for Question 23 = 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)
																	(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

* Actinide 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
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