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 15 May 2023

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 ▶

P71940A

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P 7 1 9 4 0 A 0 1 2 8

Pearson

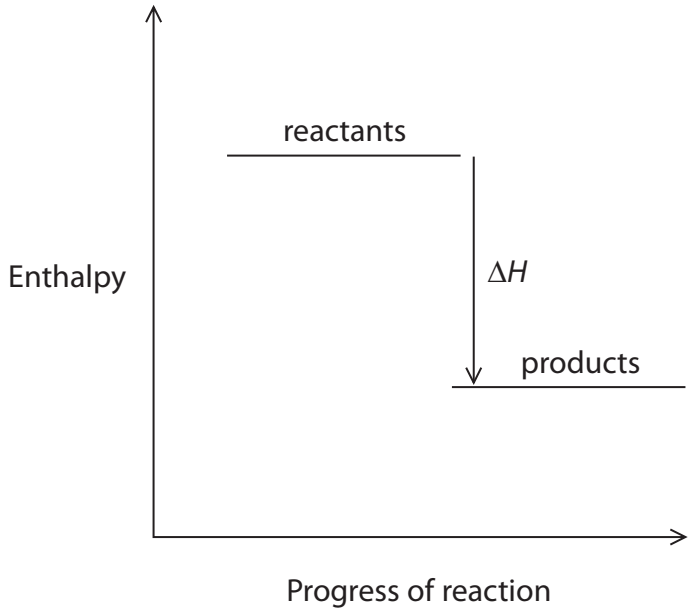
SECTION A

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 The enthalpy level diagram for a reaction is shown.



Which is represented by this diagram?

☒ **A** $Na(s) \rightarrow Na(g)$

☒ **B** $Na(g) \rightarrow Na^+(g) + e^-$

☒ **C** $2Cl(g) \rightarrow Cl_2(g)$

☒ **D** $NH_4NO_3(s) + aq \rightarrow NH_4^+(aq) + NO_3^-(aq)$

(Total for Question 1 = 1 mark)

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

2 Excess zinc powder is added to 50.00 g of 0.500 mol dm^{-3} copper(II) sulfate solution in a polystyrene cup.
The mixture is stirred and the maximum temperature change determined.

The enthalpy change for the reaction is calculated to be –185 kJ mol^{-1}.

The data book value for this reaction is –217 kJ mol^{-1}.

(a) The percentage error in this experiment is

(1)

☒ **A** ±7.37 %

☒ **B** ±8.65 %

☒ **C** 14.7 %

☒ **D** 17.3 %

(b) In the calculation, the specific heat capacity of the liquid is taken to be 4.18 J g^{-1} $°C^{-1}$ rather than the true value of 3.85 J g^{-1} $°C^{-1}$.

The use of 4.18 J g^{-1} $°C^{-1}$ in the calculation

(1)

☒ **A** is partly responsible for the error in the final value obtained

☒ **B** lowers the error in the final value obtained

☒ **C** has a negligible effect on the final value obtained

☒ **D** has a negligible effect compared with the measurement uncertainties

(Total for Question 2 = 2 marks)

3 The enthalpy changes for two reactions are shown.

$$2Fe(s) + 1\tfrac{1}{2}O_2(g) \rightarrow Fe_2O_3(s) \qquad \Delta_r H^{\ominus} = -824\ kJ\ mol^{-1}$$

$$C(s) + \tfrac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta_r H^{\ominus} = -111\ kJ\ mol^{-1}$$

What is the enthalpy change for the reaction between iron(III) oxide and carbon?

$$Fe_2O_3(s) + 3C(s) \rightarrow 2Fe(s) + 3CO(g)$$

☒ **A** +491 kJ mol^{-1}

☒ **B** +713 kJ mol^{-1}

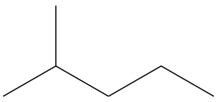
☒ **C** –491 kJ mol^{-1}

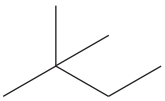
☒ **D** –713 kJ mol^{-1}

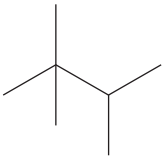
(Total for Question 3 = 1 mark)

4 Which of these alkanes would be expected to have the **highest** boiling temperature?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 4 = 1 mark)

5 The boiling temperature of hexane is 69 °C and that of cyclohexane is 81 °C.

The main reason that cyclohexane has a higher boiling temperature is that cyclohexane molecules

☒ **A** have more electrons

☒ **B** have strong permanent dipole-permanent dipole forces

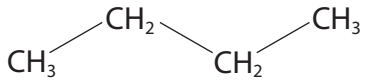
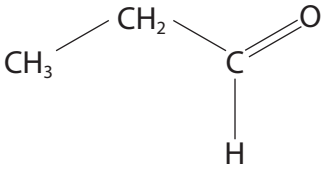
☒ **C** have a larger surface area of contact

☒ **D** form hydrogen bonds

(Total for Question 5 = 1 mark)

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

6 The structures and boiling temperatures of butane and propanal are shown.

Butane	Propanal
	
$T_b = 0\,°C$	$T_b = 49\,°C$

The main reason that propanal has a higher boiling temperature is that propanal molecules

- ☒ **A** have more electrons
- ☒ **B** have strong permanent dipole-permanent dipole forces
- ☒ **C** have a larger surface area of contact
- ☒ **D** form hydrogen bonds

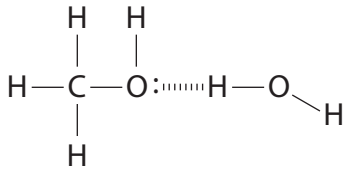
(Total for Question 6 = 1 mark)

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

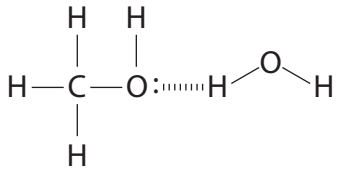
7 Hydrogen bonds are formed when methanol dissolves in water.

Which structure best represents a hydrogen bond between methanol and water?

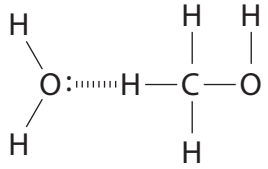
☒ **A**



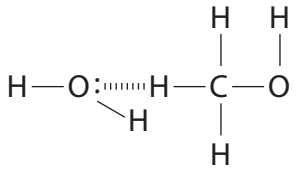
☒ **B**



☒ **C**



☒ **D**



(Total for Question 7 = 1 mark)

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

8 In which pair of compounds is the stated element in the **same** oxidation state?

- ☒ **A** chlorine in Cl_2O_7 and $Ca(ClO_3)_2$
- ☒ **B** chromium in $K_2Cr_2O_7$ and K_2CrO_4
- ☒ **C** manganese in K_2MnO_4 and Mn_2O_7
- ☒ **D** oxygen in K_2O and K_2O_2

(Total for Question 8 = 1 mark)

9 What is the formula of barium(II) ferrate(VI)?

- ☒ **A** Ba_2FeO_3
- ☒ **B** $BaFeO_3$
- ☒ **C** Ba_2FeO_4
- ☒ **D** $BaFeO_4$

(Total for Question 9 = 1 mark)

10 When lithium reacts with excess oxygen, only lithium oxide is formed.
When sodium reacts with excess oxygen, sodium oxide and sodium peroxide are both formed.

What is the main reason why sodium peroxide is formed?

- ☒ **A** sodium is more reactive than lithium
- ☒ **B** sodium has a lower first ionisation energy than lithium
- ☒ **C** the sodium ion has a larger ionic radius than the lithium ion
- ☒ **D** the sodium ion has a higher charge density than the lithium ion

(Total for Question 10 = 1 mark)

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

11 A piece of sodium weighing 1.15 g reacts completely with distilled water and the solution formed is made up to 250.0 cm^3.

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

What is the concentration of the sodium hydroxide solution?

- ☒ **A** 0.025 mol dm^{-3}
- ☒ **B** 0.050 mol dm^{-3}
- ☒ **C** 0.100 mol dm^{-3}
- ☒ **D** 0.200 mol dm^{-3}

(Total for Question 11 = 1 mark)

12 Magnesium nitrate decomposes on heating.

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

A sample of magnesium nitrate decomposed completely.

The total volume of gas formed was 1200 cm^3, measured at room temperature and pressure (r.t.p.).

What mass of magnesium nitrate was used?

[M_r $Mg(NO_3)_2$ = 148.3 Molar volume of gas at r.t.p. = 24 000 cm^3 mol^{-1}]

- ☒ **A** 1.48 g
- ☒ **B** 2.97 g
- ☒ **C** 7.42 g
- ☒ **D** 14.8 g

(Total for Question 12 = 1 mark)

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

13 When solid sodium chloride is placed in a Bunsen flame, a persistent yellow colour is observed.

The yellow colour is due to

- ☒ **A** electrons being excited to higher energy levels and emitting yellow light on returning to the ground state
- ☒ **B** electrons being excited to higher energy levels and emitting blue-violet light on returning to the ground state
- ☒ **C** electrons being excited to higher energy levels and absorbing yellow light
- ☒ **D** electrons being excited to higher energy levels and absorbing blue-violet light

(Total for Question 13 = 1 mark)

14 In a series of experiments, the time taken to complete the reaction between iron(III) sulfate and sodium thiosulfate in aqueous solution is measured.

One drop of a solution of a substance is added to separate reaction mixtures. The results are shown.

Substance added	Reaction time / s
(no substance)	205
copper(II) sulfate	75
lead(II) nitrate	464
sodium nitrate	204
zinc sulfate	202

Which ion speeds up the reaction?

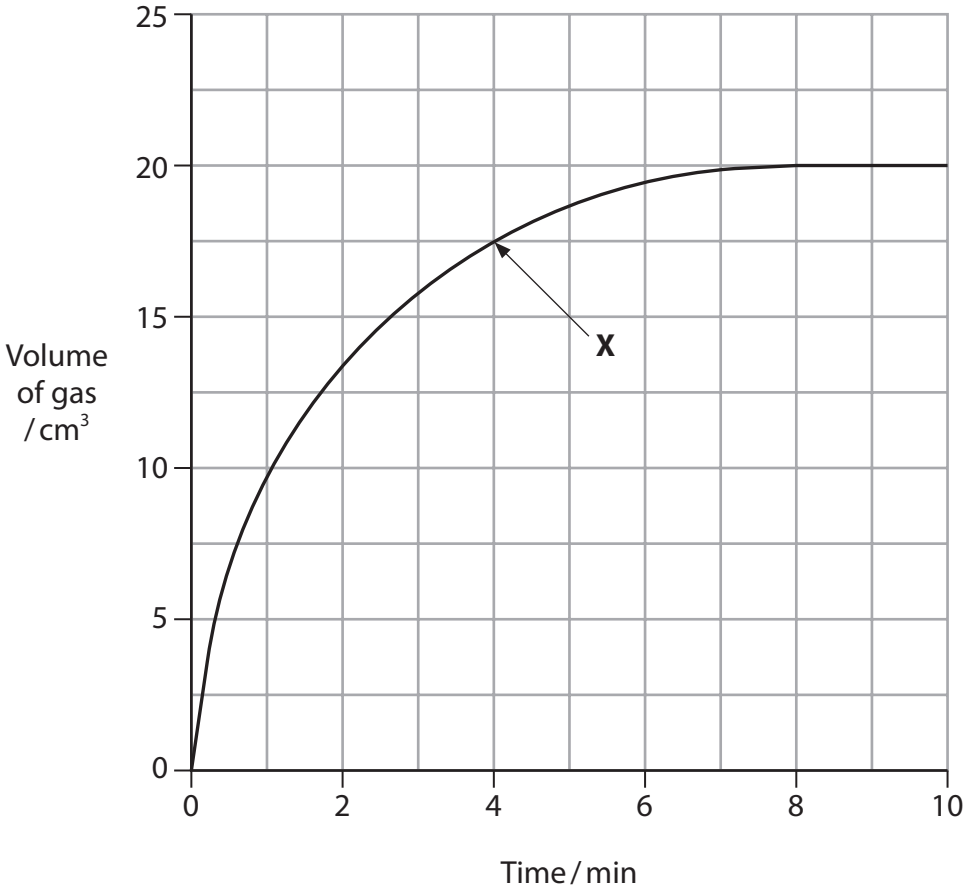
- ☒ **A** copper(II)
- ☒ **B** lead(II)
- ☒ **C** nitrate
- ☒ **D** sulfate

(Total for Question 14 = 1 mark)

15 Hydrogen peroxide decomposes in the presence of a catalyst.

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

The volume of gas formed is measured at regular time intervals and the data plotted on a graph.



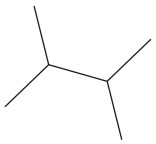
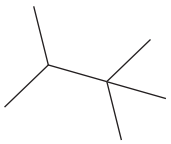
What is the rate of formation of oxygen at point **X**?

- ☒ **A** 1.3 $cm^3 min^{-1}$
- ☒ **B** 2.5 $cm^3 min^{-1}$
- ☒ **C** 4.4 $cm^3 min^{-1}$
- ☒ **D** 25 $cm^3 min^{-1}$

(Total for Question 15 = 1 mark)

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

16 The structures of three bromoalkanes **P**, **Q** and **R** are shown.

		
P	**Q**	**R**

Which of these bromoalkanes may be classified as tertiary?

- ☒ **A** **P** only
- ☒ **B** **Q** only
- ☒ **C** **R** only
- ☒ **D** **Q** and **R** only

(Total for Question 16 = 1 mark)

17 When 1-chlorobutane is mixed with ethanol and aqueous silver nitrate, a reaction occurs.

Which species is the nucleophile in this reaction?

- ☒ **A** ethanol
- ☒ **B** nitrate ions
- ☒ **C** silver ions
- ☒ **D** water

(Total for Question 17 = 1 mark)

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

18 Propan-1-ol may be converted into propene.

$$CH_3CH_2CH_2OH \rightarrow CH_3CH{=}CH_2 + H_2O$$

(a) Which reagent is used for this reaction?

(1)

- ☒ **A** 50 % sulfuric acid
- ☒ **B** ethanolic potassium hydroxide
- ☒ **C** phosphoric(V) acid
- ☒ **D** red phosphorus

(b) The reaction is best classified as

(1)

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

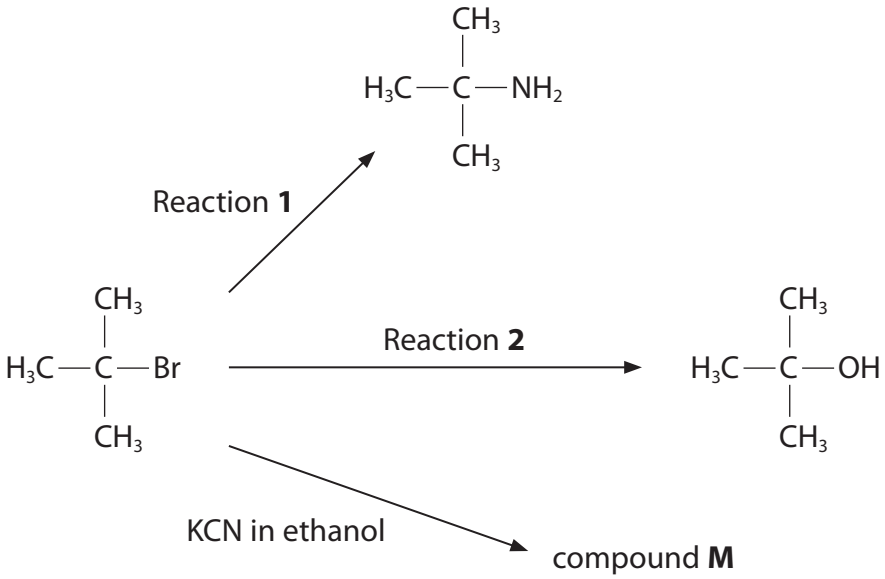
(Total for Question 18 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

19 Some reactions of a halogenoalkane are summarised in the diagram.
All the reactions are of the same type and mechanism.



(a) Name the type and mechanism of these reactions.

(1)

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(b) Give the IUPAC name and the structure of compound **M**.

(2)

.....

(c) State the reagent and conditions required for Reaction **1**.

(2)

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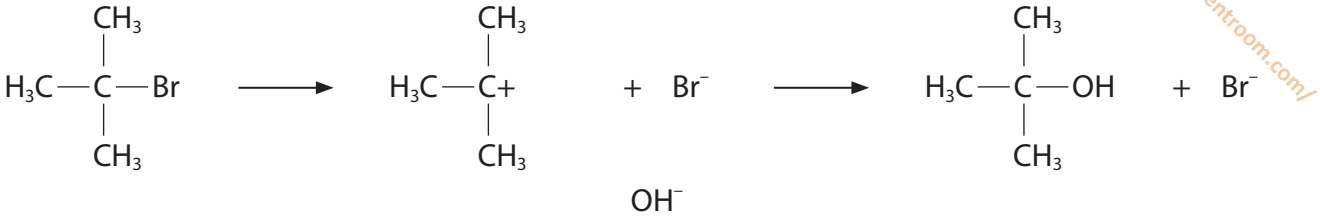
(d) An incomplete mechanism for Reaction **2** is shown.



intermediate **J**

(i) Complete the mechanism by adding curly arrows, and relevant dipoles and lone pairs.

(2)

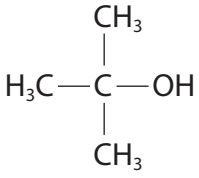
(ii) Describe how intermediate **J** is formed in the first step, naming the process that occurs.

(2)

(iii) State the shape of intermediate **J**. Justify your answer.

(2)

(iv) The product of Reaction **2** is shown.



This compound has three isomers that are also alcohols.

Draw the structures of these isomers.

(2)

isomer 1	isomer 2	isomer 3

(e) The reaction of halogenoalkanes with hydroxide ions is often carried out using sodium hydroxide or potassium hydroxide.

An alternative is 'moist silver(I) oxide', which is prepared by adding a few drops of water to solid silver(I) oxide.

Silver(I) oxide is insoluble in water but produces sufficient hydroxide ions for the reaction.

(i) Write the **ionic** equation for the reaction of silver(I) oxide with water. State symbols are not required.

(2)

(ii) Suggest **one** advantage of using silver(I) oxide rather than sodium hydroxide or potassium hydroxide.

(1)

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(Total for Question 19 = 16 marks)

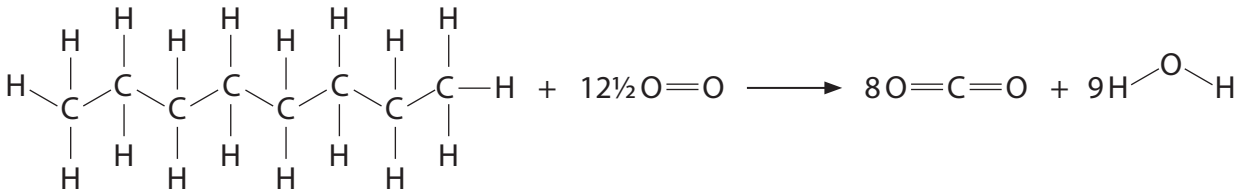
20 This question is about fuels.

The enthalpy change of combustion is the maximum amount of heat energy that can be obtained by the complete combustion of a substance.

Values for the enthalpy change of combustion may be obtained by direct measurement or from mean bond enthalpies. These data may be used to assess the efficiency of fuels.

Petrol is a mixture of a large number of different hydrocarbons containing between four and twelve carbon atoms. Octane, C_8H_{18}, is a typical component of petrol.

(a) The equation for the combustion of octane is shown.



(i) Use mean bond enthalpies to calculate a value for the enthalpy change of combustion of octane.

(4)

Bond	C—C	C—H	O—H	O=O	C=O
Mean bond enthalpy / kJ mol^{-1}	347	413	464	498	805

(ii) The standard enthalpy change of combustion, $\Delta_c H^{\ominus}$, of octane is $-5470\,kJ\,mol^{-1}$.

Give **two** reasons why this value, measured under standard conditions, is different from the value obtained using bond enthalpy data.

(2)

(iii) When petrol is used to power a car, the energy available is less than the theoretical maximum.
When one kilogram of petrol powers a car, the energy used to move the car is 11 MJ.

Calculate the percentage of the maximum energy that is available to move a car, assuming that this fuel is pure octane.

Use $\Delta_c H^{\ominus} = -5470\,kJ\,mol^{-1}$.

(2)

(iv) Give **two** reasons why the energy used to move the car is less than the theoretical maximum.

(2)

*(b) Two alternatives to hydrocarbon fuels are hydrogen and ammonia.
Hydrogen burns to form water as the only product but hydrogen is extremely hard to liquefy. Ammonia is easily liquefied but it is toxic.

Compare and contrast the intermolecular forces involved when hydrogen and ammonia liquefy, by describing how these forces are formed.

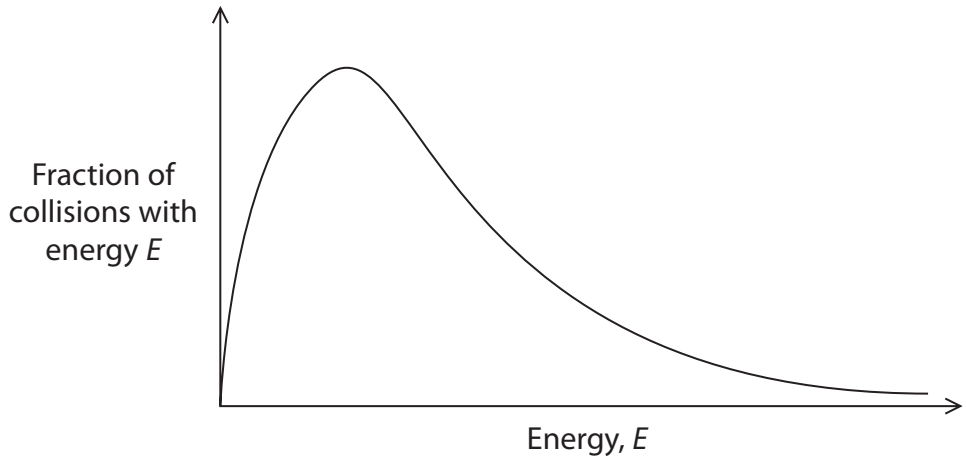
(6)

(Total for Question 20 = 16 marks)

21 Methanal is used in the production of many materials and chemical compounds. It is manufactured from methanol by reaction with oxygen at 300–400 °C using an iron-molybdenum oxide catalyst.

$$CH_3OH(g) + \tfrac{1}{2}O_2(g) \rightarrow HCHO(g) + H_2O(g)$$

(a) The Maxwell–Boltzmann distribution for the reaction mixture at 300 °C is shown.



(i) On the diagram, sketch the Maxwell–Boltzmann distribution for this reaction mixture at a **higher** temperature.

(1)

(ii) Using the Maxwell–Boltzmann distributions, explain why increasing the temperature and adding a catalyst both increase the rate of reaction.

(2)

(b) An alternative method for producing methanal uses a silver catalyst at a temperature of 650 °C. The reaction is shown.

$$CH_3OH(g) \rightarrow HCHO(g) + H_2(g)$$

Suggest **one** advantage and **one** disadvantage of this method, other than the cost of the silver catalyst.

(2)

Advantage

.....

.....

Disadvantage

.....

.....

(c) Explain how the infrared spectra of methanol and methanal can be used to distinguish between the two compounds, stating the relevant bond stretching vibrations and their wavenumber ranges.

(2)

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(Total for Question 21 = 7 marks)

TOTAL FOR SECTION B = 39 MARKS

SECTION C

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

22 Toilet Cleaners

Products used to clean toilets work in two ways: removing the limescale that collects in the toilet bowl and disinfecting the bowl.

Limescale contains calcium carbonate which is removed by reaction with acids. The strongest acid used in toilet cleaners is hydrochloric acid, although weaker acids such as methanoic acid are also used.

Disinfectants are essentially chlorine dissolved in aqueous sodium hydroxide. The effective disinfectant in these solutions is the chlorate(I) ion, ClO^-.

(a) State **one** safety precaution that you should take when using a toilet cleaner containing hydrochloric acid.

(1)

.....

(b) The equation for the reaction of calcium carbonate with hydrochloric acid is shown.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

(i) Write the **ionic** equation for this reaction.
State symbols are not required.

(1)

(ii) A 750 cm^3 bottle of a toilet cleaner contains 85.0 g of hydrochloric acid.

Calculate the maximum mass of calcium carbonate limescale that could be removed by 50.0 cm^3 of this toilet cleaner.

(4)

(c) Chlorine gas reacts with water.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HClO(aq) + HCl(aq)$$

(i) State the classification of this reaction. Justify your answer in terms of the relevant oxidation numbers.

(3)

(ii) When 5.00 cm^3 of a disinfectant reacts with excess hydrogen peroxide, 113 cm^3 of oxygen is produced, measured at room temperature and pressure.

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

Calculate the concentration, in g dm^{-3}, of sodium chlorate(I) in the disinfectant. Give your answer to **two** significant figures.

(4)

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

(iii) Commercial disinfectants are often made more viscous by adding propane-1,2,3-triol to the aqueous solution.

Suggest how propane-1,2,3-triol makes disinfectants more viscous.

(2)

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(d) Toilet cleaners that remove limescale should not be mixed with chlorine-based disinfectants.

Explain, using the relevant equation, why these two types of toilet cleaner should not be mixed.

(2)

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(e) Borax is another cleaning agent used to remove limescale.

Borax is a compound of sodium, boron and oxygen.
Borax crystals contain water of crystallisation.

The percentage composition by mass of some borax crystals is
H = 5.2 % B = 11.3 % O = 71.4 % Na = 12.1 %

Determine the empirical formula of the borax crystals and hence their formula.

(4)

(Total for Question 22 = 21 marks)

TOTAL FOR SECTION C = 21 MARKS
TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

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)
																	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							

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1.0 **H** hydrogen 1

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