EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2018
General Certificate of Education Advanced Level
Higher 1

CHEMISTRY

8873/01

Paper 1 Multiple Choice

24 September 2018

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, civics group and index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this question paper.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **9** printed pages and **1** blank page.

1 A giant molecule contains a large amount of carbon of isotopes ^{12}C and ^{13}C. It was found that the relative atomic mass of carbon in the molecule is 12.20.

What is the ratio of ^{12}C to ^{13}C in the molecule?

A 4:1 **B** 3:1 **C** 1:3 **D** 1:4

2 A 30 cm^3 sample of butane, C_4H_{10}, was completely reacted in a limited supply of oxygen to produce 60 cm^3 of carbon dioxide and 60 cm^3 of carbon monoxide.

All volumes were measured at room temperature and pressure.

Which volume of oxygen was used?

A 90 cm^3 **B** 120 cm^3 **C** 150 cm^3 **D** 165 cm^3

3 Molybdenum can form many complex oxy-ions. It has been reported that a complex molybdenum oxyanion can self-assemble to a large doughnut-shaped structure with a 3.6 nm diameter.

The oxyanion unit has the formula $[Mo_{36}O_{112}(H_2O)_{16}]^{8-}$.

Calculate the oxidation state of molybdenum in this oxyanion unit.

A +3 **B** +4 **C** +5 **D** +6

4 Carbon monoxide reduces iodine(V) oxide to iodine.

$$5CO + I_2O_5 \rightarrow 5CO_2 + I_2$$

This reaction can be used to estimate carbon monoxide quantitatively as the liberated iodine can be reacted with sodium thiosulfate.

How many moles of thiosulfate ions would reduce the iodine produced from 1 mole of carbon monoxide in the above equation?

A 0.1 **B** 0.4 **C** 2.0 **D** 2.5

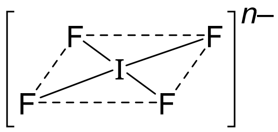
5 Which of the following particles would have a half-filled set of p orbitals on losing an electron?

A Si^- **B** P **C** P^- **D** S^+

6 Which of the following organic molecules does **not** have a permanent dipole?

A C_2Cl_4 **B** CF_2Cl_2 **C** $CHCl_3$ **D** CF_2CCl_2

7 An ion IF_4^{n-} has a square planar structure as shown below.



What is the value of *n*?

A 1 **B** 2 **C** 3 **D** 4

8 When 13.08 g of zinc was added to 250 cm^3 of 1.0 mol dm^{-3} aqueous copper(II) sulfate, the temperature of the solution rose by 15 ºC.

$$Cu^{2+}(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + Cu(s)$$

What is the enthalpy change (in kJ mol^{-1}) for the above reaction?
[Specific capacity of the final solution is 4.20 J g^{-1} K^{-1}.]

A –1512 **B** –79.1 **C** –78.8 **D** –4.12

9 Which of the following will have a positive ΔH value?

1 $\frac{1}{2}O_2(g) \longrightarrow O(g)$

2 $O_2(g) + 2e^- \longrightarrow O_2^{2-}(g)$

3 $O_2(g) + O(g) \longrightarrow O_3(g)$

A **1**, **2** and **3**

B **1** and **2** only

C **2** and **3** only

D **1** only

10 The lattice energy of rubidium fluoride, RbF, is –760 kJ mol^{-1} and the lattice energy of caesium chloride, CsC*l*, is –650 kJ mol^{-1}

Which value is likely to be the lattice energy of caesium fluoride, CsF, in kJ mol^{-1}?

A –460 **B** –550 **C** –680 **D** –800

11 Consider the following equilibrium reaction:

$$3Fe(s) + 4H_2O(g) \quad Fe_3O_4(s) + 4H_2(g)$$

Which of the following gives the units for the equilibrium constant, K_c?

A mol dm^{-3} **B** mol^{-2} dm^6 **C** mol^4 dm^{-12} **D** no units

12 Two students set up the equilibrium system below.

$$CH_3COOC_2H_5(l) + H_2O(l) \quad C_2H_5OH(l) + CH_3COOH(l)$$

The students titrated samples of the equilibrium mixture with NaOH(aq), to determine the concentration of CH_3COOH.

The students used their results to calculate a value for K_c, but their values were different.

Which of the reason(s) below could explain why the calculated values for K_c were different?

1 Each student carried out their experiment at a different temperature.

2 Each student used a different concentration of NaOH(aq) in their titration.

3 Each student titrated a different volume of the equilibrium mixture.

A **1**, **2** and **3**

B **1** and **2** only

C **2** and **3** only

D **1** only

13 20.0 cm^3 of 0.10 mol dm^{-3} sulphuric acid, H_2SO_4, was mixed with 20.0 cm^3 of 0.10 mol dm^{-3} aqueous sodium hydroxide. The following reaction occurs

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

What is the pH of the resulting solution?

A 1.0 **B** 1.3 **C** 1.6 **D** 7.0

14 The hydrolysis of sucrose in aqueous solution is catalysed by hydrogen ions, such as from hydrochloric acid.

Which of the following procedures can be used to determine the order of the reaction with respect to hydrogen ions?

A Measure the rate of the reaction several times, but with a different concentration of hydrochloric acid each time.

B Add a suitable indicator and watch for the time when the colour changes.

C Remove samples at various time intervals and titrate against a standard solution of sodium hydroxide.

D Measure the change in pH during the reaction.

15 Consider the oxides of the Period 3 elements.
Which property decreases from Na_2O to SiO_2 and also from SiO_2 to P_4O_{10}?

A covalent character

B melting point

C pH when mixed with water

D solubility in aqueous alkali

16 Aluminium is the third most abundant element in the Earth's crust.

Which of the following statements is **not** true of the element and its compounds?

A Aluminium chloride exists as a dimer in solid state.

B A solution of aluminium chloride turns blue litmus red.

C Aluminium oxide dissolves in both aqueous acids and aqueous alkalis.

D Aluminium fluoride has a much higher melting point than aluminium bromide.

17 Element **G** is found in Period 3 of the Periodic Table.

The oxide and chloride of element **G** are separately mixed with water. The two resulting solutions have the same effect on litmus paper.

What is the identity of element **G**?

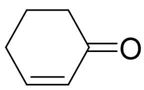
A aluminium

B magnesium

C phosphorus

D sodium

18 How many σ and π bonds are there in a molecule of the cyclohex-2-enone?



cyclohex-2-enone

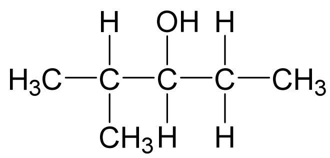
	σ	π
A	5	4
B	7	2
C	8	2
D	15	2

19 The alkynes are a series of hydrocarbons containing one C≡C triple bond per molecule. They have the general formula C_nH_{2n-2}.

How many **structural** isomers are there for the alkyne containing six carbon atoms per molecule?

A 3 **B** 5 **C** 6 **D** 7

20 How many different alkenes, including geometrical isomers, could be produced when



reacts with hot concentrated sulfuric acid?

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

21 Compound **X** has the molecular formula $C_4H_{10}O_2$.

X has an unbranched carbon chain and contains two OH groups.

On reaction with an excess of hot, acidified, aqueous manganate(VII) ions, **X** is converted into a compound of molecular formula $C_4H_6O_4$.

To which two carbon atoms in the chain of **X** are the two OH groups attached?

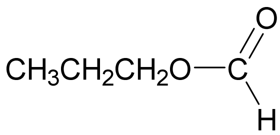
A 1st and 2nd

B 1st and 3rd

C 1st and 4th

D 2nd and 3rd

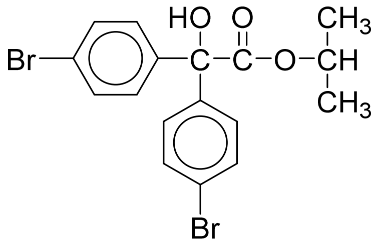
22 The structural formula of a compound **X** is shown below.



What is the name of compound **X** and how does its boiling point compare with that of butanoic acid?

	name of **X**	boiling point of **X**
A	methyl propanoate	higher
B	methyl propanoate	lower
C	propyl methanoate	higher
D	propyl methanoate	lower

23 *Acarol* is sold as an insecticide for use on fruit and vegeta



Acarol

The final stage in its manufacture is an esterification reaction.

Which alcohol is used in the final stage to form *Acarol*?

A propan-2-ol

B propan-1-ol

C methanol

D di(4-bromophenyl)methanol

24 Propan-1-ol is heated with Al_2O_3. The organic product is then reacted with bromine.
What is the final product/s of these two reactions?

A 1-bromopropane

B 1-bromopropane and 2-bromopropane

C 1,2-dibromopropane

D 1,3-dibromopropane

25 A bromine-containing organic compound, **T**, undergoes an elimination reaction when treated with hot ethanolic sodium hydroxide solution.

Which compound could be **T**?

A CH_3Br

B C_2Br_6

C $CH_3CH_2CBr_3$

D $(CH_3)_2C{=}CBr_2$

26 "Clearfilm" is manufactured from a polymer made by copolymerising $CH_2{=}CHCl$ with $CH_2{=}CCl_2$ in a regular 'head to tail' linkage, where CH_2 is taken as the 'head' of each monomer.

Which of the following could represent parts of the polymer chain in "Clearfilm'

1 —CHC*l*—CH_2—CCl_2—

2 —CH_2—CHC*l*—CH_2—

3 —CH_2—CHC*l*—CCl_2—

A **1** and **2** only

B **1** and **3** only

C **2** and **3** only

D **1**, **2** and **3**

27 Nylon 6 has the following formula and undergoes acidic hydrolysis.

$$-\!\!\left(NH(CH)_5CO\right)_n\!\!-$$

What is the product of the acidic hydrolysis of Nylon 6?

A $HO_2C(CH_2)_4CO_2H$

B $H_3\overset{+}{N}(CH_2)_6\overset{+}{N}H_3$

C $H_3\overset{+}{N}(CH_2)_5CHO$

D $H_3\overset{+}{N}(CH_2)_5CO_2H$

28 Poly(ethene) and PVC are examples of addition polymers.
Which statements are correct?

1 On combustion, PVC can produce carbon monoxide, carbon dioxide and hydrogen chloride.

2 When poly(ethene) is buried in a landfill site, it will biodegrade when in contact with bacteria.

3 The empirical formula of an addition polymer is the same as that of the monomer.

A **1** and **2** only

B **1** and **3** only

C **2** and **3** only

D **1**, **2** and **3**

29 Chemists have recently synthesised the smallest "beakers" for carrying out chemical reactions. The "beakers" are the junctions from a network of hollow polymer nanofibres. The volume of the beakers is about 4×10^{-18} dm^3.

A "beaker" is full of a solution of glucose of concentration 5×10^{-4} mol dm^{-3}.

Calculate the number of glucose molecules in the "beaker".

A 602 **B** 1204 **C** 1806 **D** 2408

30 Which of the following uses are attributed to the high surface to volume ratio of nanoparticles?

1 The use of graphene in tennis rackets.

2 The use of silver nanoparticles to treat wounds.

3 The use of platinum nanoparticles as catalyst in catalytic converter in cars.

4 Colloidal solution of silver nanoparticles is used in painting as it appears yellow.

A **1**, **2** and **3** only

B **2**, **3** and **4** only

C **2** and **3** only

D **3** and **4** only

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Answer :

Question	Answer	Question	Answer
1	**A**	16	**A**
2	**D**	17	**C**
3	**D**	18	**D**
4	**B**	19	**D**
5	**C**	20	**B**
6	**A**	21	**C**
7	**A**	22	**D**
8	**C**	23	**A**
9	**B**	24	**C**
10	**C**	25	**C**
11	**D**	26	**A**
12	**D**	27	**D**
13	**B**	28	**B**
14	**A**	29	**B**
15	**C**	30	**B**

2018 JC2 Preliminary Examination
H1 Chemistry 8873
Paper 1 Worked Solution

1 Let the % of ^{12}C by x%.
So there is $(100-x)\%$ of ^{13}C.

$$\frac{12x+13(100-x)}{100}=12.20$$
$$1300-x=1220$$
$$x=80$$

$\therefore\ ^{12}C:^{13}C=80:20=4:1$

$\Rightarrow$ **A**

2 $C_4H_{10}+\frac{13}{2}O_2 \rightarrow 4CO_2+5H_2O$

$C_4H_{10}+\frac{9}{2}O_2 \rightarrow 4CO+5H_2O$

Since the same volume of CO and CO_2 is produced, we have $n_{CO}=n_{CO_2}$:

$$2C_4H_{10}+11O_2 \rightarrow 4CO+4CO_2+10H_2O$$

Volume of $O_2=\frac{11}{2}\times30=165\ cm^3$

$\Rightarrow$ **D**

3 $\text{O.S. of Mo}=+\frac{-8-(112\times-2)}{36}=+6$

$\Rightarrow$ **D**

4 $n_{I_2}=\frac{1}{5}n_{CO}=\frac{1}{5}\times1=0.2$ mol

$$I_2+2S_2O_3^{2-}\rightarrow 2I^-+S_4O_6^{2-}$$

$n_{S_2O_3^{2-}}=2n_{I_2}=2\times0.2=0.4$ mol

$\Rightarrow$ **B**

5 Si^- : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3 \xrightarrow{-e^-}$
Si : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

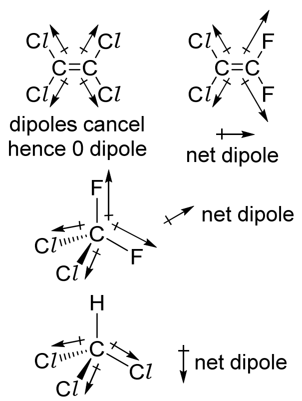
P : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3 \xrightarrow{-e^-}$
P^+ : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

P^- : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4 \xrightarrow{-e^-}$
P : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$ (half-filled p orbitals)

S^+ : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5 \xrightarrow{-e^-}$
S : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$

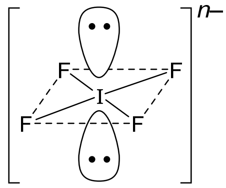
$\Rightarrow$ **C**

6 Bond dipoles are vectors which add up vectorially to give the resultant dipole of the molecules:



$\Rightarrow$ **A**

7 In order for IF_4^{n-} to adopt a square planar shape, there are two lone pairs in the structure:



Total number of electrons around I = 12
of which 4 originates from the four F atoms (contributing to the 4 I–F bonds)
and 7 from the I (Group 17) itself
Hence, n = 12 – 4 – 7 = 1 (*i.e.* the iodine had gained one electron from elsewhere, thus a –1 charge)

$\Rightarrow$ **A**

8 Heat evolved, $q=mc\Delta T$
$=250\times4.20\times15$
$=15750$ J

$n_{Zn}=\frac{13.08}{65.4}=0.200$ mol

$n_{Cu^{2+}}=\frac{250}{1000}\times1.0=0.250$ mol

Zn is the limiting reagent

Hence, $\Delta H=-\frac{q}{n_{Zn}}=-\frac{15750}{0.200}$
$=-78750\ J\ mol^{-1}$
$=-78.8\ kJ\ mol^{-1}$

$\Rightarrow$ **C**

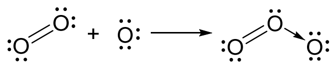
9 **1** ✓: Involves breaking the O=O in O_2 to give O atoms, hence endothermic

2 ✓: Electron affinity occurs in two stages:

$$O_2 \xrightarrow{+e^-} O_2^- \xrightarrow{+e^-} O_2^{2-}$$

The second electron affinity involves the addition of an electron to an already negative O_2^- anion, and would be highly endothermic, rendering the whole process endothermic

3 ✗: Involves the formation of a dative bond from O_2 to O atom to give O_3, and hence exothermic:



$\Rightarrow$ **B**

10 lattice energy, $L.E.\propto\left|\frac{q^+q^-}{r_++r_-}\right|$

Since $r_{Cs^+}>r_{Rb^+}$ and $r_{Cl^-}>r_{F^-}$, so the numerical value of the lattice energy of CsF will be **in between** that of CsCl and RbF

$\Rightarrow$ **C**

11 $K_c=\frac{[H_2]^4}{[H_2O]^4}$

Units of $K_c=\frac{(\text{mol dm}^{-3})^4}{(\text{mol dm}^{-3})^4}=$ dimensionless

$\Rightarrow$ **D**

12 **1** ✓: K_c changes with temperature. Hence if the students carry out the reaction at different temperatures, the values of K_c will differ

2 ✗: K_c is independent of the initial concentrations of reactants. K_c only depends on the temperature

3 ✗: K_c is independent of the amount of reactants and products. K_c only depends on the temperature

$\Rightarrow$ **D**

13 $n_{H_2SO_4}=\frac{20.0}{1000}\times0.10=0.00200$ mol

$n_{NaOH}=\frac{20.0}{1000}\times0.10=0.00200$ mol

Hence H_2SO_4 is in excess

$n_{\text{excess }H_2SO_4}=0.00200-\frac{1}{2}\times0.00200$
$=0.00100$ mol

$[H^+]=\frac{2n_{\text{excess }H_2SO_4}}{\frac{20.0+20.0}{1000}}=\frac{0.00200}{\frac{40.0}{1000}}$
$=0.0500\ mol\ dm^{-3}$

$pH=-lg[H^+]=-lg(0.0500)=1.30$

$\Rightarrow$ **B**

14 If H^+ are catalyst, $[H^+]$ does not change as the reaction progresses, and hence a concentration-time plot (horizontal straight line) will not give information on order of reaction w.r.t. H^+.

Thus **B**, **C** and **D** which relies on a change in $[H^+]$ with time does not work.

A which investigates the relationship between rate of reaction and $[H^+]$ directly is the only valid method.

$\Rightarrow$ **A**

15 **A** ✗: Covalent character ↑es from Na_2O to SiO_2, but remains covalent from SiO_2 to P_4O_{10}

B ✗: Melting point ↑es from Na_2O to SiO_2, but ↓es from SiO_2 to P_4O_{10}

C ✓: pH of solution of Na_2O (=14), MgO (=9), Al_2O_3 and SiO_2 (=7, insoluble), P_4O_{10} (=2)

D ✗: Na_2O is soluble, MgO is sparingly soluble and SiO_2 is insoluble in aqueous alkali (requires heating with concentrated NaOH), but P_4O_{10} is soluble in aqueous alkali

$\Rightarrow$ **C**

16 **A** ✓: $AlCl_3$ is ionic is the solid state, becoming the covalent dimer only upon melting

B ✗: $AlCl_3$ undergoes extensive hydrolysis in water to give an acidic solution of HCl, turning blue litmus red:

$$AlCl_3+3H_2O\rightarrow Al(OH)_3+3HCl$$

C ✗: Al_2O_3 is amphoteric:

$$Al_2O_3+6HCl\rightarrow 2AlCl_3+3H_2O$$
$$Al_2O_3+2NaOH+3H_2O\rightarrow 2NaAl(OH)_4$$

D ✗: $r_{F^-}<r_{Br^-}$, $\therefore L.E.\propto\left|\frac{q^+q^-}{r_++r_-}\right|$ of AlF_3 is more exothermic than that of $AlBr_3$, reflected in the higher melting point

$\Rightarrow$ **A**

17 **A ✗**: Al_2O_3 is insoluble hence neutral (pH 7), while $AlCl_3$ is acidic in water (pH 3)

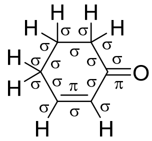
B ✗: MgO is slightly soluble giving pH 9, while $MgCl_2$ undergoes slight hydrolysis to give pH 6.5

C ✓: P_4O_{10} is acidic in water (pH = 2) and PCl_5 is also acidic in water (pH = 2)

D ✗: Na_2O is alkaline in water (pH 14) while NaC*l* is neutral (pH 7)

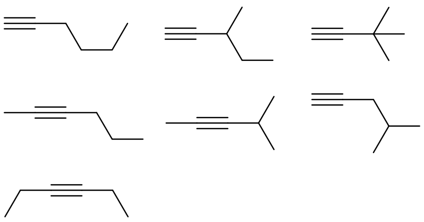
⇒ **C**

18 Structure of cyclohexanone, including H:



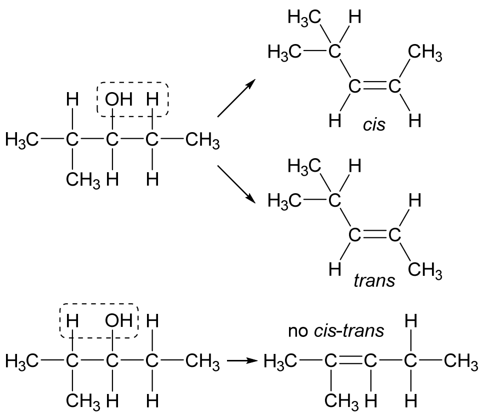
⇒ **D**

19 The structural isomers are



⇒ **D**

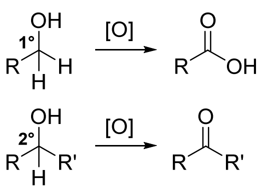
20 Elimination can occur with the H on both sides of the OH:



⇒ **B**

21 $C_4H_{10}O_2$ is saturated, hence is a diol, with 2 OH groups.

Oxidation with $KMnO_4$ gives $C_4H_6O_4$, with loss of 4H and gain of 2O. Hence both alcohols are 1° alcohols:



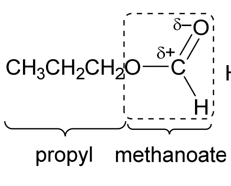
–2H +1O

–2H

Since the **X** has an unbranched carbon chain, the OH groups must be on carbon 1 and 4.

⇒ **C**

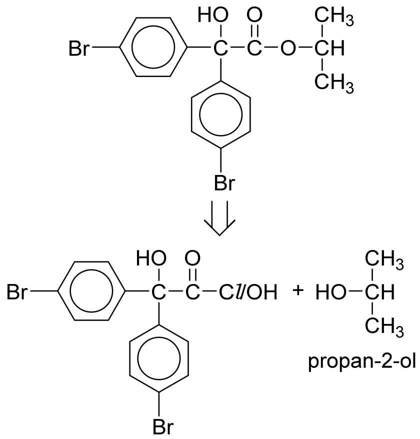
22



can only form pd-pd interaction and not H bond like in RCO_2H, hence lower b.p.

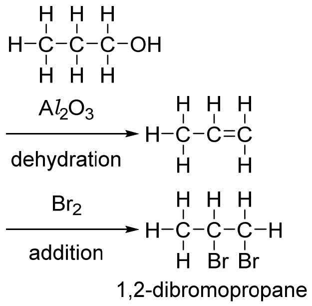
⇒ **D**

23



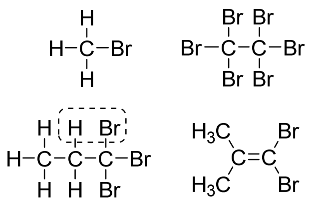
⇒ **A**

24



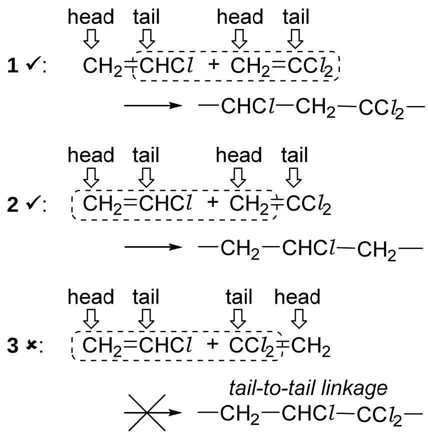
⇒ **C**

25



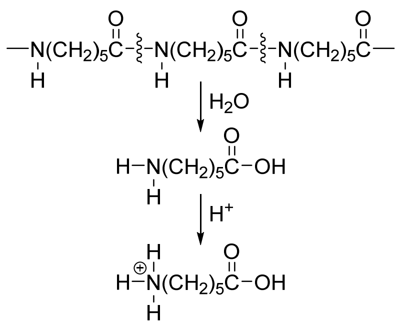
⇒ **C**

26 Only head-to-tail linkage is allowed.



⇒ **A**

27 Hydrolysis of the amide linkage:



⇒ **D**

28 **1 ✓**: PVC contains C, H and C*l*, hence will form (H_2O,) CO, CO_2 and HC*l* upon combustion.

2 ✗: Poly(ethene), being a hydrocarbon, is essentially non-biodegrable.

3 ✓: An addition polymer is composed of *n* repeats of the monomer unit, hence will have the same empirical formula

⇒ **B**

29

$$
\begin{aligned}
n_{glucose} &= [\text{gluocse}] \times V_{glucose} \\
&= (5\times10^{-4}\ \text{mol dm}^{-3}) \\
&\quad \times (4\times10^{-18}\ \text{dm}^3) \\
&= 2\times10^{-21}\ \text{mol} \\
\text{No. of molecules} &= n_{glucose} \times N_A \\
&= (2\times10^{-21}\ \text{mol}) \\
&\quad \times (6.02\times10^{23}\ \text{mol}^{-1}) \\
&= 1204
\end{aligned}
$$

⇒ **B**

30 **1 ✗**: Use of graphene in tennis racquet is due to the strength of graphene sheets despite its low mass

2 ✓: Use of silver nanoparticles relies on its high surface area-to-volume ratio, which maximises the interaction between the pathogens and Ag

3 ✓: The efficiency of the catalyst depends on the surface available for the gaseous pollutants to bind to, hence the larger surface area-to-volume ratio will render the platinum nanoparticles more efficient

4 ✓: The colour of suspension of nanoparticles depends on the size of the nanoparticles due to surface plasmon resonance, involving excitation of the surface electrons. Hence changes in the surface area-to-volume ratio will affect the number of surface electrons, hence affecting the colour

⇒ **B**

Answer Key

Qn	Ans	Qn	Ans	Qn	Ans
1	A	**11**	D	**21**	C
2	D	**12**	D	**22**	D
3	D	**13**	B	**23**	A
4	B	**14**	A	**24**	C
5	C	**15**	C	**25**	C
6	A	**16**	A	**26**	A
7	A	**17**	C	**27**	D
8	C	**18**	D	**28**	B
9	B	**19**	D	**29**	B

10	C	**20**	B	**30**	B

EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2018
General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME								
CIVICS GROUP	1	7	–			INDEX NUMBER		

CHEMISTRY

8873/02

Paper 2 Structured Questions

13 September 2018

2 hours

Candidates answer **Section A** and **Section B** on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number on the work you hand in.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions in the spaces provided on the Question paper.

Section B
Answer **one** question in the spaces provided on the Question paper.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question..

For Examiner's Use	
Section A (60 marks)	
1	
2	
3	
4	
5	
Section B (20 marks)	
Total	

This document consists of 22 printed pages.

For Examiner's Use

Section A

Answer **all** the questions in this section.

1 Sulfur, atomic number 16, is found within the Earth's crust. Sulfur is released into the atmosphere at times of volcanic activity.

A sample of sulfur from a volcano was analysed to give the following composition of isotopes.

isotope	abundance (%)
^{32}S	95.02
^{33}S	0.76
^{34}S	4.22

(a) Define the term relative atomic mass.

....

....

....

....[1]

(b) Calculate the relative atomic mass of the sample of sulfur.

[1]

(c) John Dalton, an early 19th century scientist, believed that elements were made up of tiny particles called atoms which could not be divided. Nowadays, chemists know of the existence of sub-atomic particles in atoms and in ions.

Complete the table to show the number of sub-atomuration of the ^{33}S atom and $^{34}S^{2-}$ ion.

isotopic species	number of protons	number of neutrons	number of electrons	electronic configuration
^{33}S				$1s^2$ ....
$^{34}S^{2-}$				$1s^2$ ....

[4]

For Examiner's Use

(d) Solid sulfur exists as a lattice of S_8 molecules. Each S_8 molecule is a ring of eight atoms.

How many atoms of sulfur are there in 0.0120 mol of S_8 molecules?

[1]

(e) The only intermolecular forces in solid sulfur are instantaneous dipole-induced dipole.

(i) Describe how instantaneous dipole-induced dipole arise.

....

....

....

....[2]

(ii) Suggest why there are no other intermolecular forces in solid sulfur.

....

....

....[1]

(f) Sulfur hexafluoride, SF_6, exists as non-polar covalent molecules with an octahedral shape.

Explain why a molecule of SF_6 has an octahedral shape.

....

....

....

....

....[2]

[Total: 12]

2 Iodine, I_2, is a grey-black solid that is not very soluble in water.

Equilibrium 1 is set up with the equilibrium position well to the left.

$$I_2(s) \rightleftharpoons I_2(aq)$$ **equilibrium 1**

Solid iodine is much more soluble in an aqueous solution of potassium iodide, KI(aq), than in water.

Equilibrium 2 is set up.

$$I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$$ **equilibrium 2**

(a) Suggest why I_2 is **not** very soluble in water.

....

....[1]

(b) (i) Write an expression for the equilibrium constant for this reaction, K_c, stating its units.

[2]

When 2.54 g of solid iodine is dissolved in 100 cm^3 of 1.00 mol dm^{-3} KI, and allowed to reach equilibrium, the resulting $[I_3^-(aq)] = 9.98\times10^{-2}$ mol dm^{-3}.

(ii) Calculate the equilibrium values of $[I_2(aq)]$ and $[I^-(aq)]$ in this solution and hence calculate a value for K_c.

$[I_2(aq)]$ = ...

$[I^-(aq)]$ = ...

K_c = ...[3]

For Examiner's Use

For Examiner's Use

(c) The student adds an excess of aqueous silver nitrate, $AgNO_3(aq)$, to the equilibrium mixture forming a yellow AgI precipitate.

State what other observation will be seen and explain the observations in terms of both **equilibrium 1** and **equilibrium 2** and any species formed.

....

....

....

....

....[2]

(d) Two redox reactions of iodine are described below.

Reaction 1: Iodine is reacted with oxygen to form a compound with a molar mass of 333.8 g mol^{-1}.

Reaction 2: Under alkaline condition, iodine disproportionates to form iodide ions and iodate(V), IO_3^- ions.

Construct equations for these **two** reactions.

Reaction 1:

....

Reaction 2:

....[2]

[Total: 10]

3 Table 3.1 gives some data on four fuel sources: methanol, ethanol, hydrogen and octane. Octane can serve as a rough approximation of petrol.

For Examiner's Use

Table 3.1

compound	**formula**	**molar mass / g mol^{-1}**	**density / g cm^{-3}**	**ΔH_c° (298 K) / kJ mol^{-1}**	**ΔH_f° (298 K) / kJ mol^{-1}**
methanol	CH_3OH	32.0	0.793[a]	–726.0	–239.1
ethanol	C_2H_5OH	....	0.789[a]	–1367.3	–277.1
liquid hydrogen	H_2	2.0	0.0711[b]		
octane	C_8H_{18}	....	0.703[a]		–250.0

[a] At 298 K and 1 bar pressure
[b] At 20 K and 1 bar pressure

(a) Insert the missing molar mass values in the Table 3.1. [1]

(b) Calculate the density of **gaseous** hydrogen at 298 K and 1 bar pressure. Assume 1 mol of any gas occupies 24 dm^3 at 298 K and 1 bar pressure. Give your answer in g cm^{-3}.

density = ... g cm^{-3} [1]

(c) What is the value of the standard enthalpy of formation of hydrogen **gas**, H_2?

....[1]

(d) Use the information in Table 3.2 to give the value of the standard enthalpy of combustion of hydrogen at 298 K.

Table 3.2

compound	**ΔH_f° (298 K) / kJ mol^{-1}**
water	–285.8
carbon dioxide	–393.5

ΔH_c° of hydrogen at 298 K = ...kJ mol^{-1} [1]

For Examiner's Use

(e) Write down the chemical equation that represents the *standard enthalpy of combustion* of octane. Include state symbols.

....[1]

(f) Use the enthalpy of formation data in Table 3.1 and Table 3.2 and the equation in **(e)** to calculate the standard enthalpy of combustion, $\Delta H_c^{\ominus}$, of octane.

[2]

(g) An important property of a fuel, especially when the fuel has to be lifted (such as in aviation), is the energy released on combustion *per gram* of fuel.

Calculate the enthalpy change of combustion per gram of fuel at 1 bar pressure and 298 K for methanol and hydrogen gas.

(i) methanol

$\Delta H_c^{\ominus}$ = ... kJ g^{-1} [1]

(ii) hydrogen gas

$\Delta H_c^{\ominus}$ = ... kJ g^{-1} [1]

For Examiner's Use

(h) Another important characteristic of a fuel, especially when there is a fuel tank of limited size, is the energy released on combustion *per cm³* of fuel.

Calculate the enthalpy change of combustion per cm^3 of fuel for ethanol and octane.

(i) ethanol

$\Delta H_c^\ominus$ = ... kJ cm^{-3} [1]

(ii) octane

$\Delta H_c^\ominus$ = ... kJ cm^{-3} [1]

(i) Explain why, given the data in the question, it is not strictly possible to make a fair comparison of the energy released per cm^3 of liquid hydrogen with the other fuels.

....

....[1]

[Total: 12]

For Examiner's Use

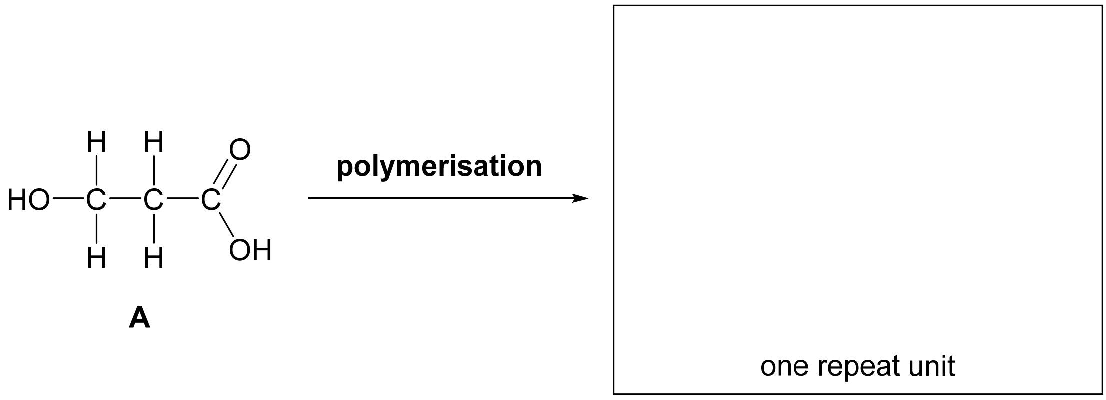
4 (a) 3-Hydroxypropanoic acid, $HOCH_2CH_2COOH$, can be produced microbiologically from sugars in corn. $HOCH_2CH_2COOH$ can be used as a 'green' starting material for the synthesis of many organic compounds including some important polymers.

Three synthetic routes are shown below for converting $HOCH_2CH_2COOH$ (**A**) into different polymers.

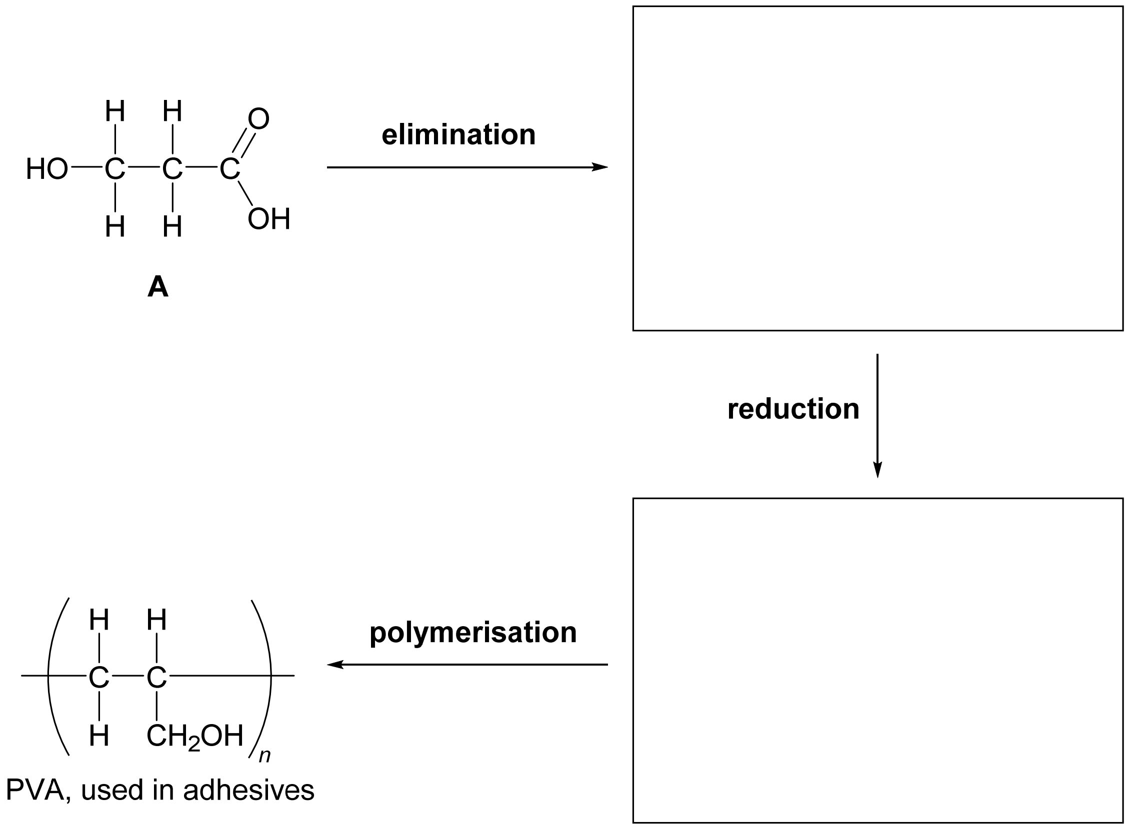
The names of the processes for each synthetic step are given.

(i) In the boxes below, give the structures of the organic compounds formed.

<u>Synthesis 1</u>

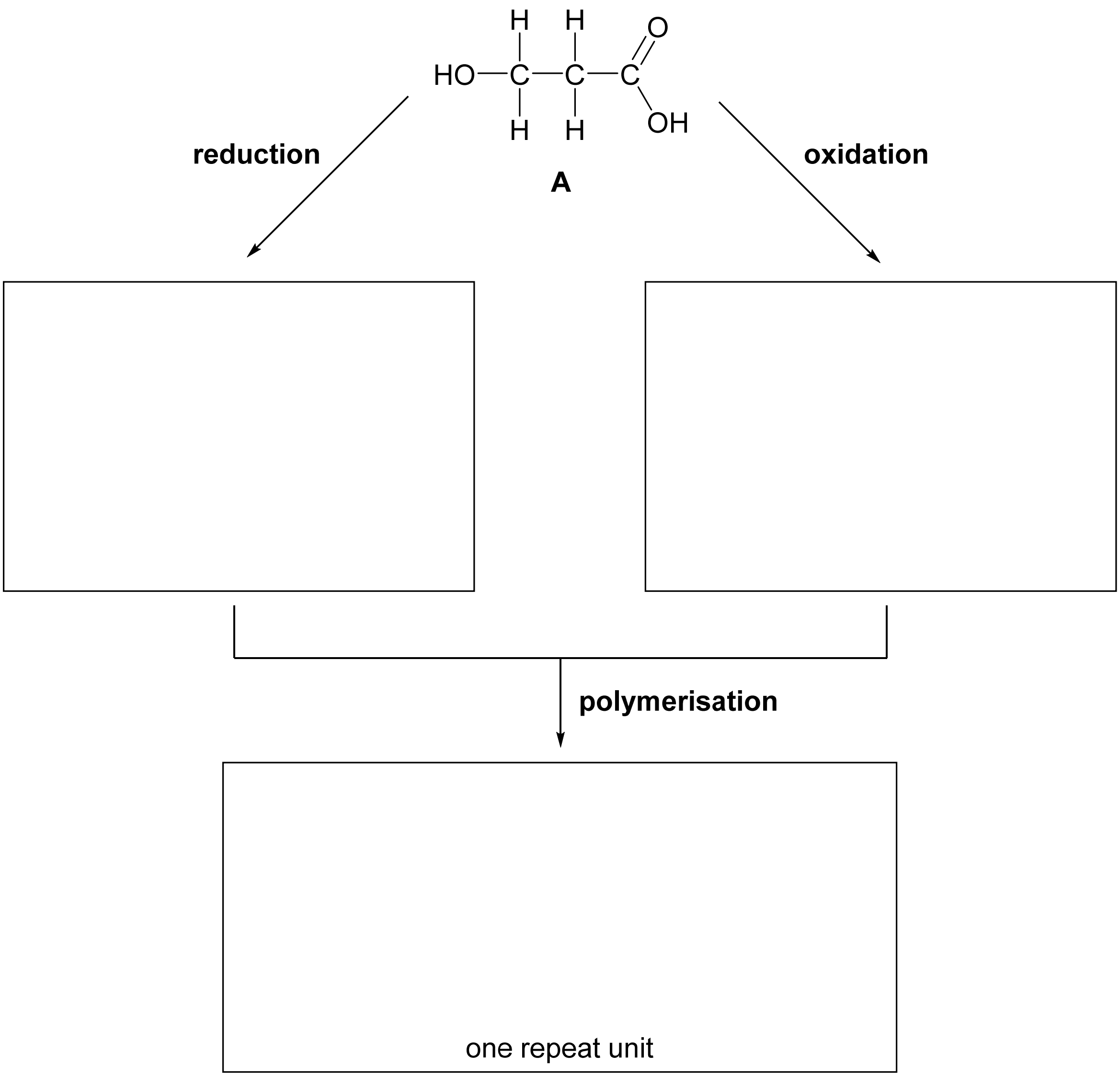


<u>Synthesis 2</u>



For Examiner's Use

Synthesis 3



[6]

(ii) State the type of polymerisation taking place in each synthetic route.

Synthesis 1: .... polymerisation

Synthesis 2: .... polymerisation

Synthesis 3: .... polymerisation [1]

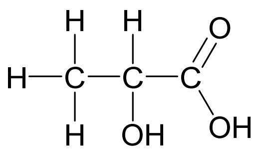
(iii) Name the reagent and condition used in the **reduction** process in **synthesis 3**

....[1]

(iii) Name the reagent and condition used in the **oxidation** process in **synthesis 3**

....[1]

(b) 2-Hydroxypropanoic acid, also known as lactic acid, has structure shown below.



For Examiner's Use

(i) When heated strongly, lactic acid forms a cyclic 'diester'.

The diester has the molecular formula, $C_6H_8O_4$.

Draw the structure of the cyclic diester.

[1]

(ii) Poly(lactic acid), PLA, is used to make 'dissolvable' stitches (for holding wounds together). PLA breaks down into smaller molecules after one or two weeks.

Draw the structure of **one** repeat unit in PLA.

[1]

(iii) Explain how PLA breaks down and why the stitches 'dissolve'.

....

....

....

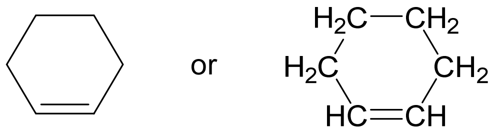
....

....[2]

[Total: 13]

For Examiner's Use

5 Cyclohexene behaves as a typical alkene.



(a) **(i)** Give the name of the type of polymerisation that cyclohexene undergoes.

....[1]

(ii) Draw a section of the polymer consisting of **three** repeat units.

[1]

(iii) A sample of cyclohexene is polymerised to a relative molecular mass of 2500, on average.

Calculate the number of complete cyclohexene units that polymerise in each polymer molecule on average. Show your working.

number of cyclohexene units = ... [1]

(b) Cyclohexene will react with hydrogen.

(i) Write an equation for the reaction.

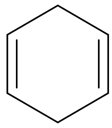
[1]

(ii) State the conditions required.

....[1]

For Examiner's Use

(c) Cyclohexa-1,4-diene also displays reactivity typical of alkenes. Its structure is shown.



Draw the structures of all possible products of the reaction when one molecule of cyclohexa-1,4-diene completely reacts with two molecules of **hydrogen bromide**.

[2]

(d) A graphene sheet is a layer of graphite.

A recent development has been the synthesis of graphene ribbons (reported in Nature, 2010). A reaction scheme is shown Fig. 5.1.

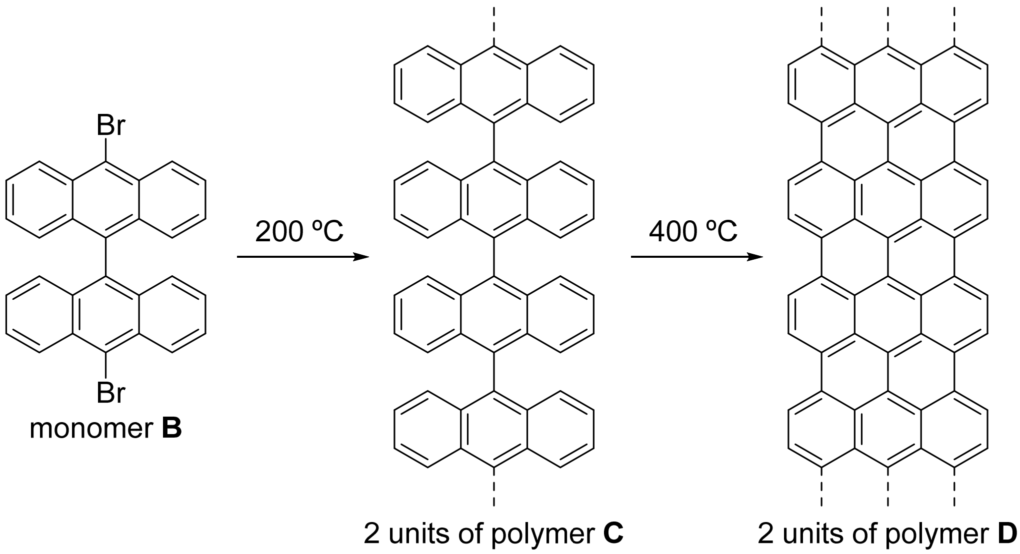


Fig. 5.1

(i) When monomer **B** is polymerised to make **C** there is also another product, **X**.

Give the molecular formula of **X**.

X is .... [1]

For Examiner's Use

(ii) In the transformation of polymer **C** into polymer **D**, another product, **Y,** is produced.

Give the molecular formula of **Y**.

Y is .... [1]

(iii) Deduce the number of moles of **X** and **Y** produced per mole of monomer **B**.

number of moles of **X** = ...

number of moles of **Y** = ... [2]

(iv) Boron nitride, BN, forms sheets similar to graphene except they contain dative covalent bonds as well as covalent bonds.

Add all the possible **dative** covalent bonds between the atoms shown in the structure Fig. 5.2.

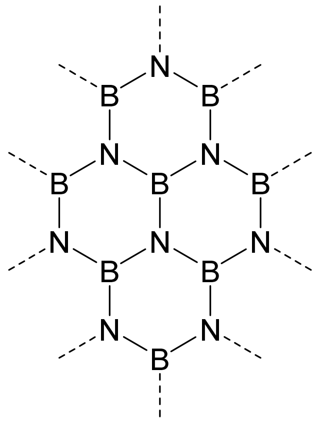


Fig. 5.2

[1]

(v) Boron nitride can also form a giant covalent structure in which each atom has four single bonds.

Suggest the name of another substance which has this type of structure.

....[1]

[Total: 13]

For Examiner's Use

Section B

Answer **one** question in this section, in the space provided.

6 (a) Under certain conditions the halogen halides decompose into their elements.

$$2HX \longrightarrow H_2 + X_2 \quad (X = Cl, Br, I)$$

(i) How can this reaction be carried out?

....[1]

(ii) Describe what will be observed in the case of HI.

....

....[1]

(iii) Use bond energy values from the *Data Booklet* to calculate ΔH for this reaction when X = Cl and when X = I.

[2]

(iv) Explain how the extent of decomposition of the hydrogen halides vary down Group 17 using the results from **(a)(iii)**.

....

....

....

....

....[2]

(b) The dissociation of water is a reversible reaction.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The ionic product of water, K_w, measures the extent of dissociation of water.

K_w varies with temperature. Therefore, it is always important to quote the temperature at which measurements are being taken.

Fig. 6.1 shows the variation of K_w between 0 ºC and 60 ºC.

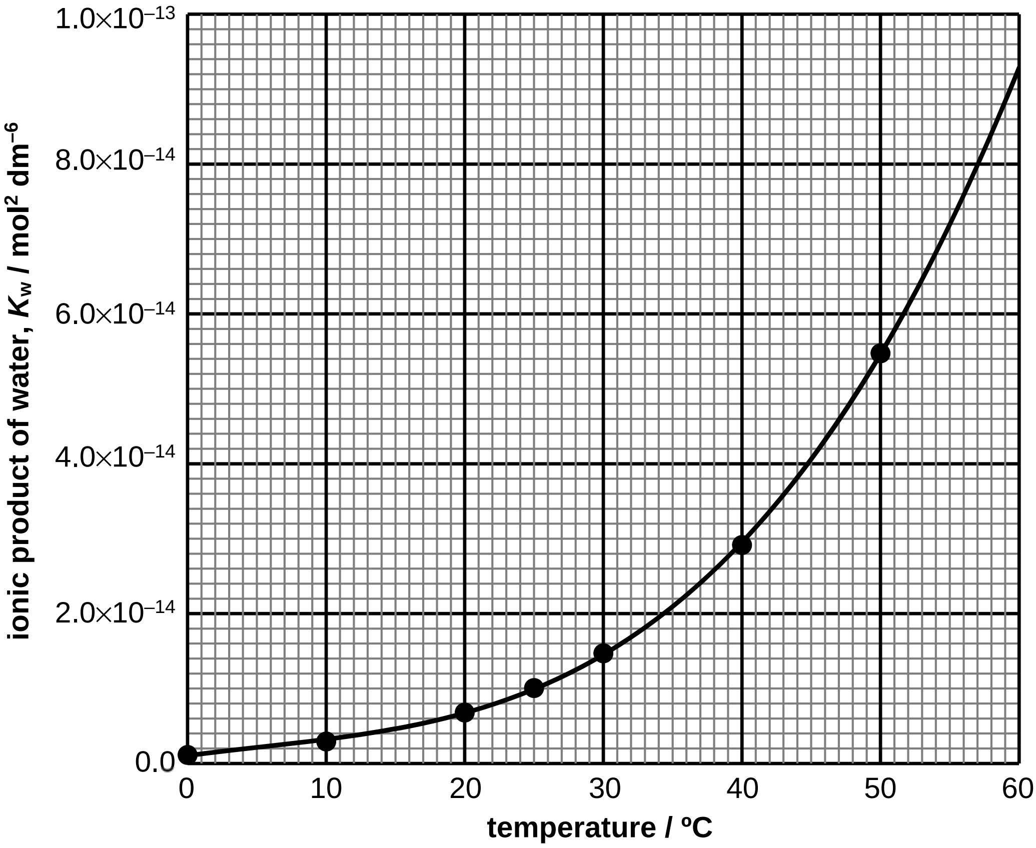


Fig. 6.1

(i) Write the expression for K_w.

....[1]

(ii) Calculate the OH^-(aq) concentration in an aqueous solution of hydrochloric acid with a pH of 4.37 at 25 ºC.

[2]

For Examiner's Use

(iii) Using Fig. 6.1, explain whether the dissociation of water is an exothermic or endothermic process.

....

....

....[1]

(iv) Determine the pH of pure water at body temperature, 37 ºC.

[3]

(c) In humans it is important for blood to be maintained at a pH between 7.35 and 7.45. One of the way it does this is by using a buffer of CO_2(aq) and HCO_3^- (aq).

During vigorous exercise the muscles produce lactic acid. Lactic acid is transported by the blood to the liver to be broken down.

(i) State the effect that exercise will have on the pH of blood if there is no buffer present.

....[1]

(ii) Write equation(s) to explain how the CO_2(aq) / HCO_3^- (aq) buffer system helps to maintain the pH of blood between 7.35 and 7.45 during exercise.

....

....

....

....

....[2]

(c) Chlorine reacts with both propane and propene, but under different conditions.

For Examiner's Use

Write equations, giving the structural formulae of the organic products, and state the conditions for the reaction of chlorine.

(i) with propane

....[2]

(ii) with propene

....[2]

[Total: 20]

For Examiner's Use

7 (a) In the presence of acid, H^+(aq), aqueous bromate(V) ions, BrO_3^- (aq), react with aqueous bromide ions, Br^-(aq), to produce bromine, Br_2(aq).

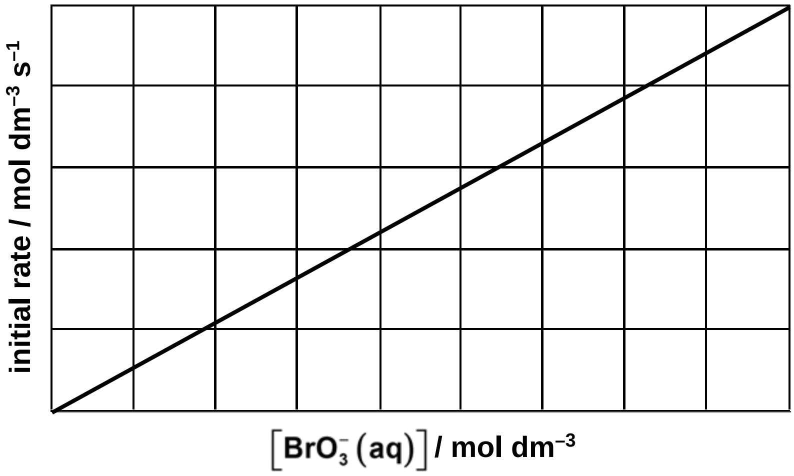
A student carried out an investigation into the kinetics of this reaction.

(i) Balance the ionic equation for this reaction.

BrO_3^- + ………. Br^- + ………. H^+ $\rightarrow$ ………. Br_2 + …….. H_2O [1]

The student investigated how different concentrations of BrO_3^- (aq) affect the initial rate of the reaction.

A graph of initial rate against $[BrO_3^-(aq)]$ is shown below.



The student then investigated how different concentrations of Br^-(aq) and H^+(aq) affect the initial rate of the reaction.

The results are shown below.

$[BrO_3^-(aq)]$ / mol dm^{-3}	$[Br^-(aq)]$ / mol dm^{-3}	$[H^+(aq)]$ / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
5.0×10^{-2}	1.5×10^{-1}	3.1×10^{-1}	1.19×10^{-5}
5.0×10^{-2}	3.0×10^{-1}	3.1×10^{-1}	2.38×10^{-5}
5.0×10^{-2}	1.5×10^{-1}	6.2×10^{-1}	4.76×10^{-5}

For Examiner's Use

(ii) Using the results from the student's experiments, determine the order of reactions with respect to all the three reactants.

order w.r.t. BrO_3^- = ...

order w.r.t. Br^- = ...

order w.r.t. H^+ = ...[3]

(iii) Write the rate equation and calculate the rate constant for this reaction, including the units.

[3]

(b) Sodium, magnesium, aluminium, silicon, phosphorus, sulfur, chlorine and neon are elements in period 3 of the periodic table.

(i) State and explain the differences between the ionic radii of Na^+, Si^{4+}, and P^{3-} and Cl^-.

....

....

....

....

....

....

....[2]

For Examiner's Use

(ii) Sodium, silicon, phosphorus and chlorine also differ greatly in their melting points. Describe how their melting points differ, and explain this variation.

....

....

....

....

....

....

....

....

....

....

....[4]

(iii) The acid-base behaviour of aluminium oxide, Al_2O_3, shows similarities to that of magnesium oxide, MgO, on the one hand, and phosphorus(V) oxide, P_4O_{10}, on the other.

Describe what these similarities are, and explain why aluminium oxide occupies this in-between position.

Write equations for all the reactions you choose to illustrate your answer.

....

....

....

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....

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....

....

....

....

....[5]

(c) Sodium borohydride, $NaBH_4$, is a useful reducing agent in organic chemistry. It reduces both propanal and propanone.

For Examiner's Use

Write balanced equations, giving the structural formulae of the organic products, to illustrate its reducing property.

(i) with propanal

....[1]

(ii) with propanone

....[1]

[Total: 20]

EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2018
General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME								
CIVICS GROUP	1	7	–			INDEX NUMBER		

CHEMISTRY

8873/02

Paper 2 Structured Questions

13 September 2018

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For Examiner's Use	
Section A (60 marks)	
1	
2	
3	
4	
5	
Section B (20 marks)	
Total	

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Section A

Answer **all** the questions in this section.

For Examiner's Use

1 Sulfur, atomic number 16, is found within the Earth's crust. Sulfur is released into the atmosphere at times of volcanic activity.

A sample of sulfur from a volcano was analysed to give the following composition of isotopes.

isotope	abundance (%)
^{32}S	95.02
^{33}S	0.76
^{34}S	4.22

(a) Define the term relative atomic mass.

Average / weighted / mean mass of the an atom of an element compared to

1/12th the mass of a ^{12}C **[1m, for both]** (atom) *or*

The **mass of 1 mole** of an element compared to 1/12th the **mass of 1 mole of ^{12}C**

[1]

(b) Calculate the relative atomic mass of the sample of sulfur.

$$\text{relative atomic mass of sulfur} = \frac{(95.02\times32)+(0.76\times33)+(4.22\times34)}{100}$$

$$= 32.092$$

$$\approx \underline{32.1} \text{ (to 1 d.p.)}$$ **[1m]**

[1]

(c) John Dalton, an early 19th century scientist, believed that elements were made up of tiny particles called atoms which could not be divided. Nowadays, chemists know of the existence of sub-atomic particles in atoms and in ions.

Complete the table to show the number of sub-atomic particles in and the electronic configuration of the ^{33}S atom and $^{34}S^{2-}$ ion.

isotopic species	number of protons	number of neutrons	number of electrons	electronic configuration
^{33}S	16	17	16	$1s^2$ $2s^2\ 2p^6\ 3s^2\ 3p^4$ **[1m]**
$^{34}S^{2-}$	16	18	18	$1s^2$ $2s^2\ 2p^6\ 3s^2\ 3p^6$ **[1m]**

[1m] (for protons, neutrons, electrons of ^{33}S) **[1m]** (for protons, neutrons, electrons of $^{34}S^{2-}$)

[4]

For Examiner's Use

(d) Solid sulfur exists as a lattice of S_8 molecules. Each S_8 molecule is a ring of eight atoms.

How many atoms of sulfur are there in 0.0120 mol of S_8 molecules?

$$\text{number of sulfur atoms} = n_{S_8} \times 8 \times N_A$$
$$= 0.0120 \times 8 \times (6.02 \times 10^{23})$$
$$= 5.7792 \times 10^{22} \approx \underline{\mathbf{5.78 \times 10^{22}}}$$ **[1m]**

[1]

(e) The only intermolecular forces in solid sulfur are instantaneous dipole-induced dipole.

(i) Describe how instantaneous dipole-induced dipole arise.

Due to **uneven movement** of electrons or **distribution of electrons** **[1m]** in a molecule, which results in an **instantaneous dipole** / **temporary dipole** (in the molecule), which **induces** dipoles in **neighbouring molecules**. **[1m, for both]**

[2]

(ii) Suggest why there are no other intermolecular forces in solid sulfur.

Only **one type of atom** *or* **no (permanent) dipoles** *or* **non-polar / no polar bonds**. **[1m]**

[1]

(f) Sulfur hexafluoride, SF_6, exists as non-polar covalent molecules with an octahedral shape.

Explain why a molecule of SF_6 has an octahedral shape.

The central sulfur has **six σ bond pairs** and **no lone pairs** **[1m, for both]**

the bond pairs **repel** one another **equally** to **minimise repulsion**, resulting in an octahedral shape **[1m]**

[2]

[Total: 12]

2 Iodine, I_2, is a grey-black solid that is not very soluble in water.

Equilibrium 1 is set up with the equilibrium position well to the left.

$$I_2(s) \rightleftharpoons I_2(aq)$$ **equilibrium 1**

Solid iodine is much more soluble in an aqueous solution of potassium iodide, KI(aq), than in water.

Equilibrium 2 is set up.

$$I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$$ **equilibrium 2**

(a) Suggest why I_2 is **not** very soluble in water.

Iodine is **non-polar** *or* Iodine **is not able to form H bonds** with water. **[1m]**

....[1]

(b) (i) Write an expression for the equilibrium constant for this reaction, K_c, stating its units.

$$K_c = \frac{[I_3^-]}{[I_2][I^-]}$$ **[1m]** ; units: **mol^{-1} dm^3** **[1m]**

[2]

When 2.54 g of solid iodine is dissolved in 100 cm^3 of 1.00 mol dm^{-3} KI, and allowed to reach equilibrium, the resulting $[I_3^-(aq)]$ = 9.98×10^{-2} mol dm^{-3}.

(ii) Calculate the equilibrium values of $[I_2(aq)]$ and $[I^-(aq)]$ in this solution and hence calculate a value for K_c.

	$I_2(aq)$	+	$I^-(aq)$	$I_3^-(aq)$
initial conc. /mol dm^{-3}	$\frac{2.54}{253.8} / \frac{100}{1000}$ = 0.100		1.00	0
change in conc. /mol dm^{-3}	-9.98×10^{-2}		-9.98×10^{-2}	$+9.98\times10^{-2}$
equilibrium conc. /mol dm^{-3}	2.00×10^{-4}		0.9002	9.98×10^{-2}

$$K_c = \frac{[I_3^-]}{[I_2][I^-]} = \frac{9.98\times10^{-2}}{2.00\times10^{-4}\times0.9002} = 554.321 \approx \mathbf{554\ mol^{-1}\ dm^3}$$

$[I_2(aq)]$ = **2.00×10^{-4} mol dm^{-3} [1m]**

$[I^-(aq)]$ = **0.900 mol dm^{-3} [1m]**

K_c = **554** mol^{-1} dm^3 **[1m]** [3]

(c) The student adds an excess of aqueous silver nitrate, $AgNO_3$(aq), to the equilibrium mixture forming a yellow AgI precipitate.

For Examiner's Use

State what other observation will be seen and explain the observations in terms of both **equilibrium 1** and **equilibrium 2** and any species formed.

Precipitation of AgI causes **$[I^-]$** to **decrease**. This causes **equilibrium 2** to shift to the **left**, which in turn causes **$[I_2(aq)]$** to **increase**. Increase in $[I_2(aq)]$ causes **equilibrium 1** to shift to **left**. **[1m] for all**

Hence **$I_2(s)$** comes out of solution as a **black** or grey **precipitate**. **[1m]**

[2]

(d) Two redox reactions of iodine are described below.

Reaction 1: Iodine is reacted with oxygen to form a compound with a molar mass of 333.8 g mol^{-1}.

Reaction 2: Under alkaline condition, iodine disproportionates to form iodide ions and iodate(V), IO_3^- ions.

Construct equations for these **two** reactions.

Reaction 1:

$2I_2 + 5O_2 \rightarrow 2I_2O_5$ [1m]

Reaction 2:

$3I_2 + 6OH^- \rightarrow 5I^- + IO_3^- + 3H_2O$ [1m] [2]

[O] : $I_2 + 6H_2O \rightarrow 2IO_3^- + 12H^+ + 10e^-$

[R] : $I_2 + 2e^- \rightarrow 2I^-$

Combining ([O] + 5[R]):

$6I_2 + 6H_2O \rightarrow 10I^- + 2IO_3^- + 12H^+$

Add $12OH^-$ to both sides:

$6I_2 + 6H_2O + 12OH^- \rightarrow 10I^- + 2IO_3^- + 12H^+ + 12OH^-$

$\Rightarrow 6I_2 + 6H_2O + 12OH^- \rightarrow 10I^- + 2IO_3^- + 12H_2O$

$\Rightarrow 6I_2 + 12OH^- \rightarrow 10I^- + 2IO_3^- + 6H_2O$

$\Rightarrow 3I_2 + 6OH^- \rightarrow 5I^- + IO_3^- + 3H_2O$

[Total: 10]

For Examiner's Use

3 Table 3.1 gives some data on four fuel sources: methanol, ethanol, hydrogen and octane. Octane can serve as a rough approximation of petrol.

Table 3.1

compound	formula	molar mass / g mol^{-1}	density / g cm^{-3}	ΔH_c° (298 K) / kJ mol^{-1}	ΔH_f° (298 K) / kJ mol^{-1}
methanol	CH_3OH	32.0	0.793[a]	–726.0	–239.1
ethanol	C_2H_5OH	46.0	0.789[a]	–1367.3	–277.1
liquid hydrogen	H_2	2.0 [1m]	0.0711[b]		
octane	C_8H_{18}	114.0	0.703[a]		–250.0

[a] At 298 K and 1 bar pressure
[b] At 20 K and 1 bar pressure

(a) Insert the missing molar mass values in the Table 3.1. [1]

(b) Calculate the density of **gaseous** hydrogen at 298 K and 1 bar pressure.
Assume 1 mol of any gas occupies 24 dm^3 at 298 K and 1 bar pressure.
Give your answer in g cm^{-3}.

$$\text{density} = \frac{\text{molar mass}}{\text{molar volume}} = \frac{2\text{ g mol}^{-1}}{24\text{ dm}^3\text{ mol}^{-1}} = \frac{2\text{ g mol}^{-1}}{24000\text{ cm}^3\text{ mol}^{-1}}$$
$$= \mathbf{8.33\times10^{-5}\ g\ cm^{-3}}$$

density = 8.33×10^{-5} [1m] g cm^{-3} [1]

(c) What is the value of the standard enthalpy of formation of hydrogen **gas**, H_2?

0 kJ mol^{-1} [1m] [1]

(d) Use the information in Table 3.2 to give the value of the standard enthalpy of combustion of hydrogen at 298 K.

Table 3.2

compound	ΔH_f° (298 K) / kJ mol^{-1}
water	–285.8
carbon dioxide	–393.5

ΔH_c° of hydrogen at 298 K = **–285.8** [1m] kJ mol^{-1} [1]

For Examiner's Use

(e) Write down the chemical equation that represents the *standard enthalpy of combustion* of octane. Include state symbols.

$C_8H_{18}(l) + \frac{25}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$ [1m]

....[1]

(f) Use the enthalpy of formation data in Table 3.1 and Table 3.2 and the equation in **(e)** to calculate the standard enthalpy of combustion, $\Delta H_c^{\ominus}$, of octane.

$$\Delta H_c^{\ominus}(\text{octane}) = \sum \Delta H_f^{\ominus}(\text{products}) - \sum \Delta H_f^{\ominus}(\text{reactants})$$
$$= 9\Delta H_f^{\ominus}(H_2O) + 8\Delta H_f^{\ominus}(CO_2) - \Delta H_f^{\ominus}(C_8H_{18}) - \frac{25}{2}\Delta H_f^{\ominus}(O_2)$$
$$= 9(-285.8) + 8(-393.5) - (-250.0) - 0$$
$$= -5470.2 \approx \underline{\mathbf{-5470\ kJ\ mol^{-1}}}$$ **[1m]**

[2]

(g) An important property of a fuel, especially when the fuel has to be lifted (such as in aviation), is the energy released on combustion *per gram* of fuel.

Calculate the enthalpy change of combustion per gram of fuel at 1 bar pressure and 298 K for methanol and hydrogen gas.

(i) methanol

$$\Delta H_c^{\ominus}(\text{kJ g}^{-1}) = \frac{\Delta H_c^{\ominus}(\text{kJ mol}^{-1})}{\text{molar mass}} = \frac{-726\ \text{kJ}\ \cancel{\text{mol}^{-1}}}{32.0\ \text{g}\ \cancel{\text{mol}^{-1}}} = -22.6875 \approx \mathbf{-22.7\ kJ\ g^{-1}}$$

$\Delta H_c^{\ominus}$ = ...**−22.7 [1m]**.......... kJ g⁻¹ [1]

(ii) hydrogen gas

$$\Delta H_c^{\ominus}(\text{kJ g}^{-1}) = \frac{\Delta H_c^{\ominus}(\text{kJ mol}^{-1})}{\text{molar mass}} = \frac{-285.8\ \text{kJ}\ \cancel{\text{mol}^{-1}}}{2.0\ \text{g}\ \cancel{\text{mol}^{-1}}} = -142.9 \approx \mathbf{-143\ kJ\ g^{-1}}$$

$\Delta H_c^{\ominus}$ = ...**−143 [1m]**.......... kJ g⁻¹ [1]

For Examiner's Use

(h) Another important characteristic of a fuel, especially when there is a fuel tank of limited size, is the energy released on combustion *per cm³* of fuel.

Calculate the enthalpy change of combustion per cm^3 of fuel for ethanol and octane.

(i) ethanol

$$\Delta H_c^{\ominus}\left(\text{kJ cm}^{-3}\right) = \frac{\Delta H_c^{\ominus}\left(\text{kJ mol}^{-1}\right)}{\text{molar mass}} \times \text{density} = \frac{-1367.3 \text{ kJ } \cancel{\text{mol}^{-1}}}{46.0 \cancel{\text{g}} \cancel{\text{mol}^{-1}}} \times 0.789 \cancel{\text{g}} \text{ cm}^{-3}$$

$$= -23.452 \approx \mathbf{-23.5 \text{ kJ cm}^{-3}}$$

$\Delta H_c^{\ominus}$ = ...**−23.5** **[1m]**.......... kJ cm^{-3} [1]

(ii) octane

$$\Delta H_c^{\ominus}\left(\text{kJ cm}^{-3}\right) = \frac{\Delta H_c^{\ominus}\left(\text{kJ mol}^{-1}\right)}{\text{molar mass}} \times \text{density} = \frac{-5470.2 \text{ kJ } \cancel{\text{mol}^{-1}}}{114.0 \cancel{\text{g}} \cancel{\text{mol}^{-1}}} \times 0.703 \cancel{\text{g}} \text{ cm}^{-3}$$

$$= -33.7329 \approx \mathbf{-33.7 \text{ kJ cm}^{-3}}$$

$\Delta H_c^{\ominus}$ = ...**−33.7** **[1m]**.......... kJ cm^{-3} [1]

(i) Explain why, given the data in the question, it is not strictly possible to make a fair comparison of the energy released per cm^3 of liquid hydrogen with the other fuels.

The enthalpy change of combustion value for hydrogen is for 298 K, and so relates to gaseous hydrogen, not to liquid hydrogen / no account taken of different temperatures / latent heat of vaporisation of hydrogen **[1m]** ....[1]

[Total: 12]

4 (a) 3-Hydroxypropanoic acid, $HOCH_2CH_2COOH$, can be produced microbiologically from sugars in corn. $HOCH_2CH_2COOH$ can be used as a 'green' starting material for the synthesis of many organic compounds including some important polymers.

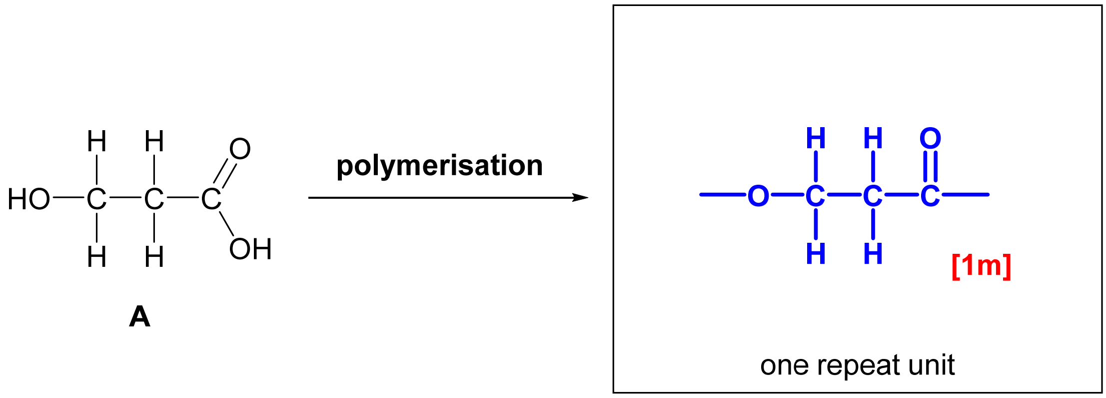
For Examiner's Use

Three synthetic routes are shown below for converting $HOCH_2CH_2COOH$ (**A**) into different polymers.

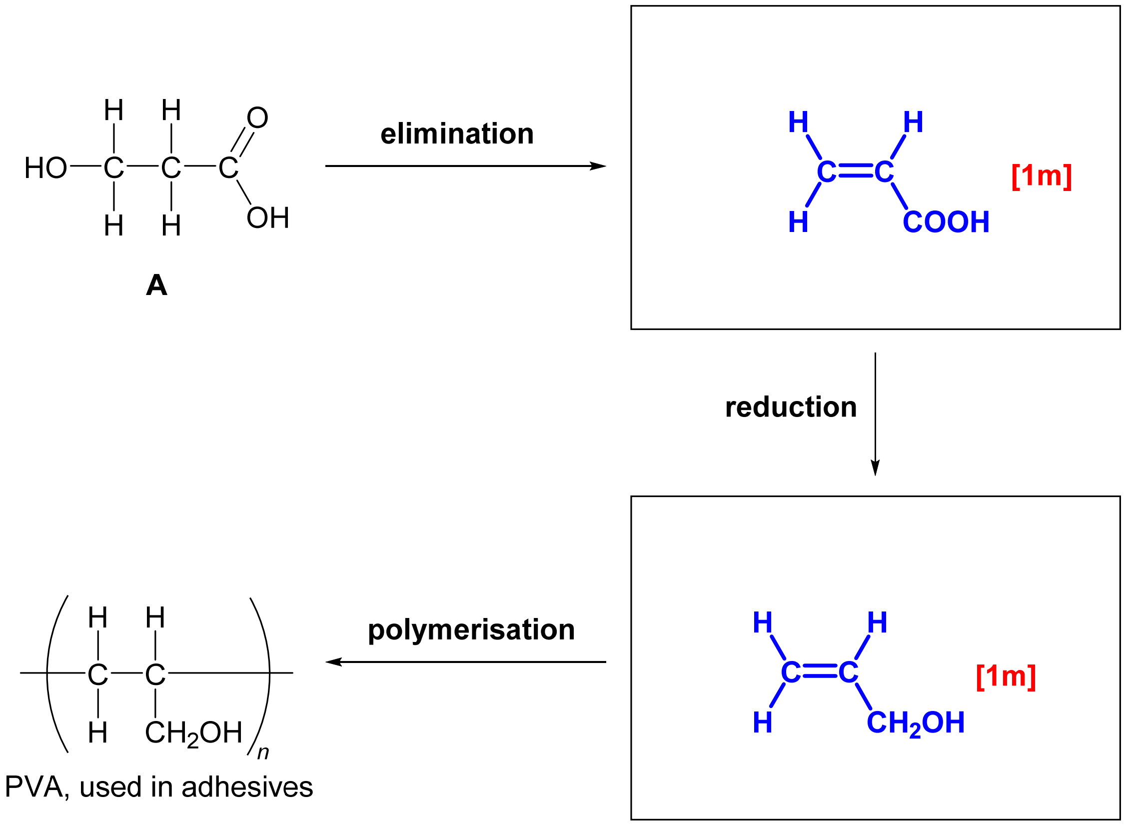
The names of the processes for each synthetic step are given.

(i) In the boxes below, give the structures of the organic compounds formed.

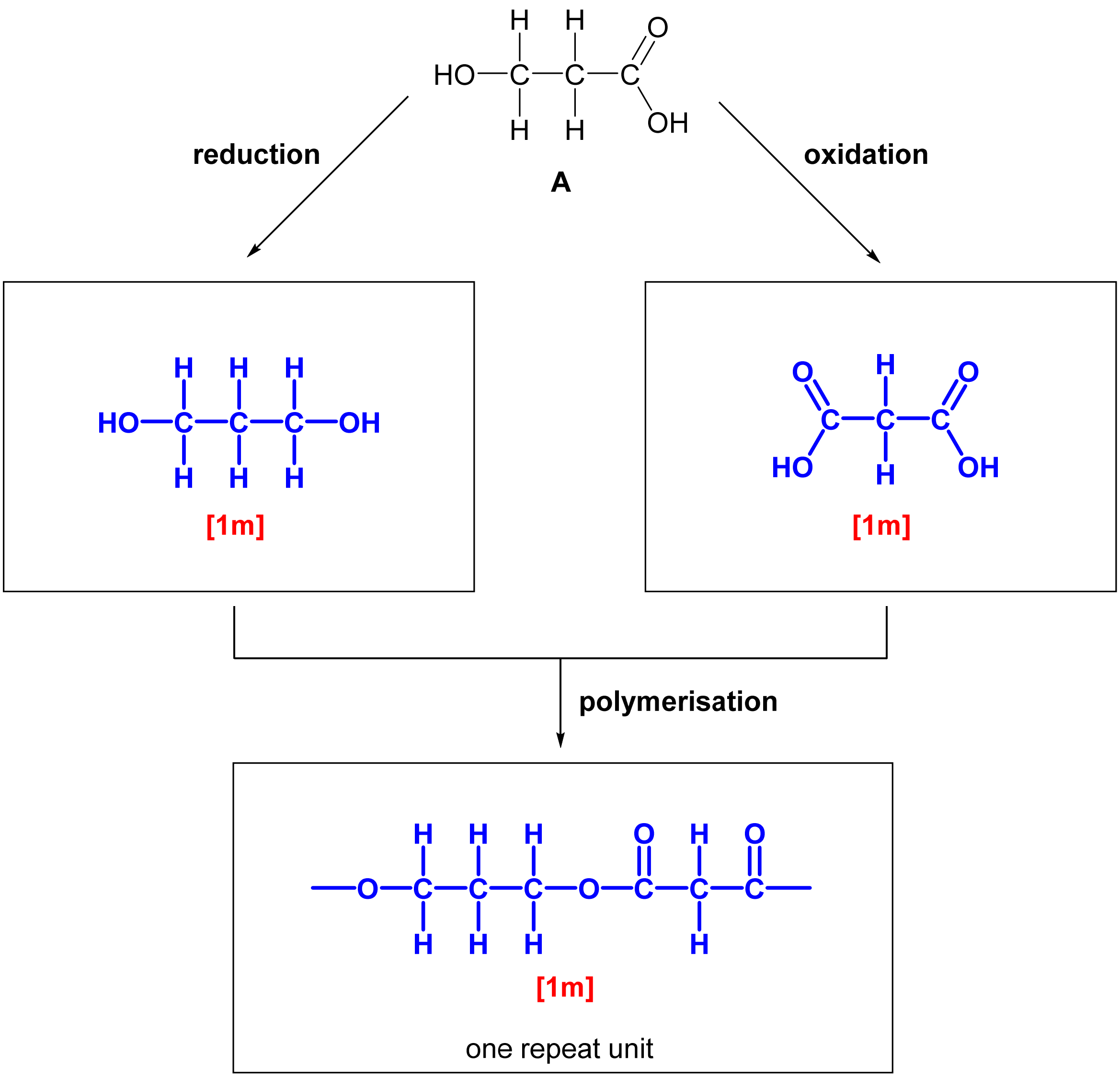
<u>Synthesis 1</u>



<u>Synthesis 2</u>



Synthesis 3



[6]

(ii) State the type of polymerisation taking place in each synthetic route.

Synthesis 1: Condensation polymerisation

Synthesis 2: Addition polymerisation

Synthesis 3: Condensation [1m, all 3] polymerisation [1]

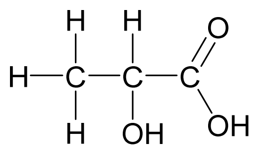
(iii) Name the reagent and condition used in the **reduction** process in **synthesis 3**

$LiAlH_4$ in dry ether, r.t. [1m] [1]

(iii) Name the reagent and condition used in the **oxidation** process in **synthesis 3**

$K_2Cr_2O_7(aq)$, $H_2SO_4(aq)$, heat with reflux [1m] [1]

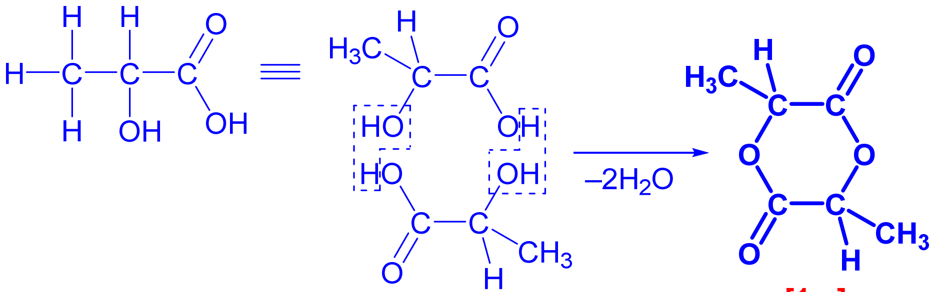
(b) 2-Hydroxypropanoic acid, also known as lactic acid, has structure shown below.



(i) When heated strongly, lactic acid forms a cyclic 'diester'.

The diester has the molecular formula, $C_6H_8O_4$.

Draw the structure of the cyclic diester.

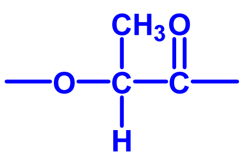


[1m]

[1]

(ii) Poly(lactic acid), PLA, is used to make 'dissolvable' stitches (for holding wounds together). PLA breaks down into smaller molecules after one or two weeks.

Draw the structure of **one** repeat unit in PLA.



[1m]

[1]

(iii) Explain how PLA breaks down and why the stitches 'dissolve'.

Ester linkages in PLA are **hydrolysed** to regenerate lactic acid **[1m]**

The lactic acid monomer is **soluble in water** because it forms **hydrogen bonds** to water **[1m]**

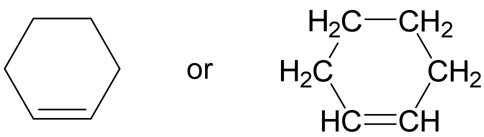
[2]

[Total: 13]

For Examiner's Use

For Examiner's Use

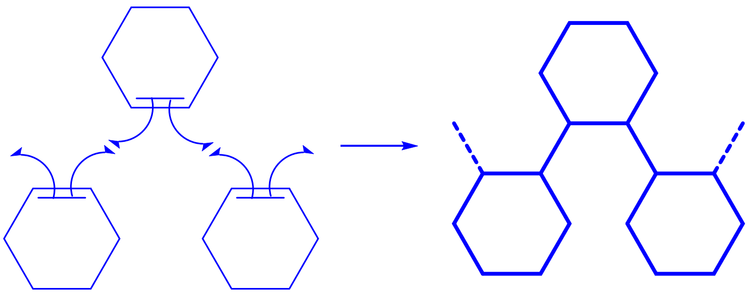
5 Cyclohexene behaves as a typical alkene.



(a) **(i)** Give the name of the type of polymerisation that cyclohexene undergoes.

Addition polymerisation **[1m]** ....[1]

(ii) Draw a section of the polymer consisting of **three** repeat units.



[1m]

Three monomer units lacking a double bond joined together correctly; dotted bonds at the ends [1]

(iii) A sample of cyclohexene is polymerised to a relative molecular mass of 2500, on average.

Calculate the number of complete cyclohexene units that polymerise in each polymer molecule on average. Show your working.

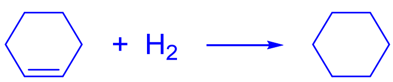
$$\text{number of complete cyclohexene units} = \frac{2500}{M_r\,(C_6H_{10})} = \frac{2500}{82} = 30.4878$$

$$\approx \underline{30}$$

number of cyclohexene units = ...**30** **[1m]**.............. [1]

(b) Cyclohexene will react with hydrogen.

(i) Write an equation for the reaction.



[1m]

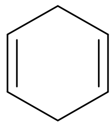
[1]

(ii) State the conditions required.

nickel catalyst at 10 atm (or **high pressure**) *or* **platinum** catalyst, **r.t.p.** **[1m]**...[1]

For Examiner's Use

(c) Cyclohexa-1,4-diene also displays reactivity typical of alkenes. Its structure is shown.



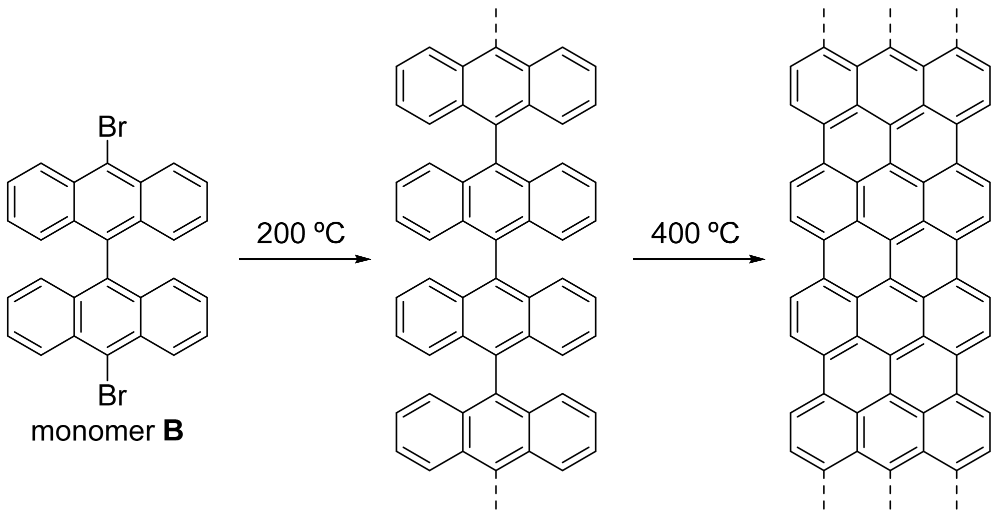
Draw the structures of all possible products of the reaction when one molecule of cyclohexa-1,4-diene completely reacts with two molecules of **hydrogen bromide**.

[1m] each

[2]

(d) A graphene sheet is a layer of graphite.

A recent development has been the synthesis of graphene ribbons (reported in Nature, 2010). A reaction scheme is shown Fig. 5.1.



2 units of polymer **C** 2 units of polymer **D**

Fig. 5.1

(i) When monomer **B** is polymerised to make **C** there is also another product, **X**.

Give the molecular formula of **X**.

X is ......Br_2 **[1m]**...... [1]

For Examiner's Use

(ii) In the transformation of polymer **C** into polymer **D**, another product, **Y,** is produced.

Give the molecular formula of **Y**.

Y is ....H_2 [1m]............ [1]

(iii) Deduce the number of moles of **X** and **Y** produced per mole of monomer **B**.

number of moles of **X** = ...1 [1m]............

number of moles of **Y** = ...4 [1m]............ [2]

(iv) Boron nitride, BN, forms sheets similar to graphene except they contain dative covalent bonds as well as covalent bonds.

Add all the possible **dative** covalent bonds between the atoms shown in the structure Fig. 5.2.

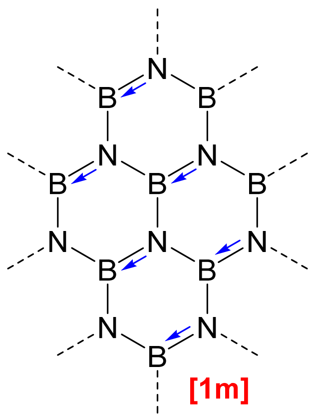


Fig. 5.2

[1]

(v) Boron nitride can also form a giant covalent structure in which each atom has four single bonds.

Suggest the name of another substance which has this type of structure.

diamond *or* **silicon** *or* **germanium** [1m] ....[1]

[Total: 13]

For Examiner's Use

Section B

Answer **one** question in this section, in the space provided.

6 **(a)** Under certain conditions the halogen halides decompose into their elements.

$$2HX \longrightarrow H_2 + X_2 \quad (X = Cl, Br, I)$$

(i) How can this reaction be carried out?

Insert a **hot wire / glass rod** into a test-tube of the gas. **[1m]** ....[1]

(ii) Describe what will be observed in the case of HI.

Purple/violet vapour of I_2 will be observed. **[1m]** ....

....[1]

(iii) Use bond energy values from the *Data Booklet* to calculate Δ*H* for this reaction when X = C*l* and when X = I.

$2HX(g) \rightarrow H_2(g) + X_2(g)$

$$\Delta H = \sum BE(\text{bonds broken}) - \sum BE(\text{bonds formed})$$
$$= 2 \times BE(\text{H—X}) - BE(\text{H—H}) - BE(\text{X—X})$$

For X = C*l* $\Delta H = 2 \times 431 - 436 - 244 =$ **+182 kJ mol^{-1}** **[1m]**

For X = I: $\Delta H = 2 \times 299 - 436 - 151 =$ **+11 kJ mol^{-1}** **[1m]**

[2]

(iv) Explain how the extent of decomposition of the hydrogen halides vary down Group 17 using the results from **(a)(iii)**.

The results from **(a)(iii)** shows that down the group, the reaction becomes **less endothermic** (or less energy is required to carry out the reaction) **[1m]**, therefore the extent of decomposition of the hydrogen halides **increases** down the group. **[1m]** ....

....[2]

(b) The dissociation of water is a reversible reaction.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The ionic product of water, K_w, measures the extent of dissociation of water.

K_w varies with temperature. Therefore, it is always important to quote the temperature at which measurements are being taken.

Fig. 6.1 shows the variation of K_w between 0 °C and 60 °C.

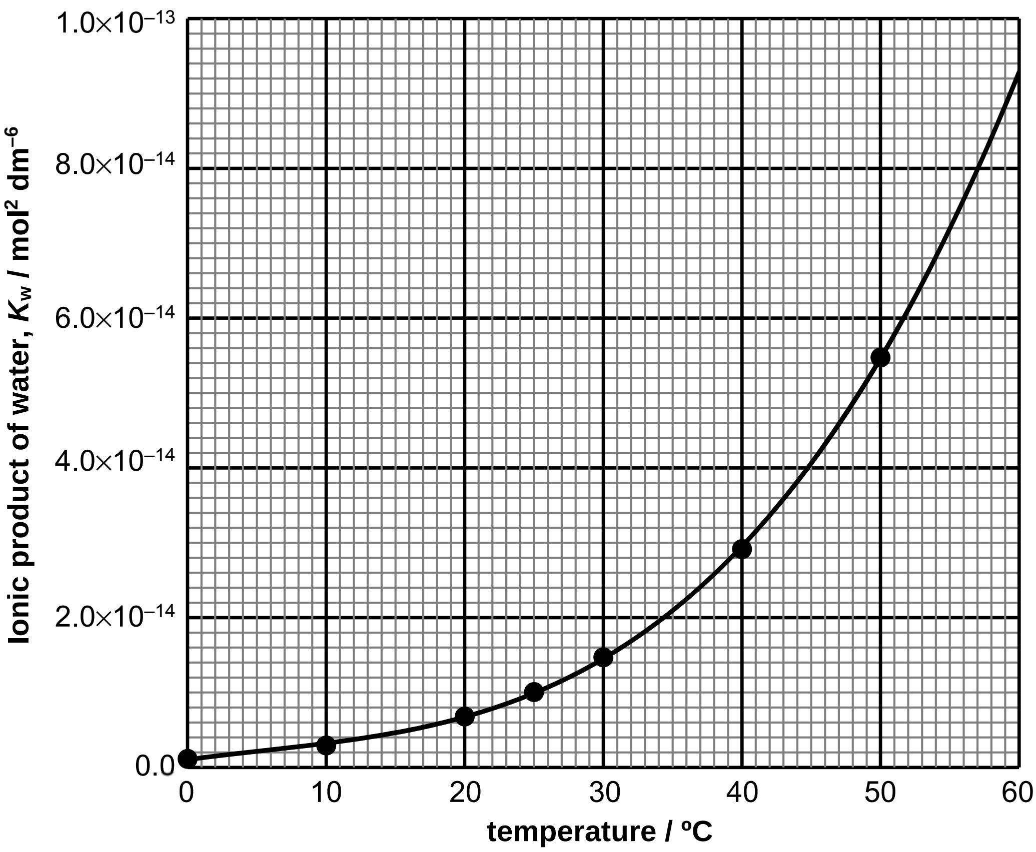


Fig. 6.1

(i) Write the expression for K_w.

$K_w = [H^+(aq)][OH^-(aq)]$ **[1m]** ....[1]

(ii) Calculate the OH^-(aq) concentration in an aqueous solution of hydrochloric acid with a pH of 4.37 at 25 °C.

$[H^+] = 10^{-pH} = 10^{-4.37} = 4.266 \times 10^{-5}$ mol dm^{-3} **[1m]**

$[OH^-] = \frac{K_w}{[H^+]} = \frac{1.0 \times 10^{-14}}{4.266 \times 10^{-5}} = 2.344 \times 10^{-10} \approx$ **2.34×10^{-10} mol dm^{-3}** **[1m]**

[2]

(iii) Using Fig. 6.1, explain whether the dissociation of water is an exothermic or endothermic process.

When temperature increases, K_w increases, *i.e.* equilibrium shift **right** to **absorb the heat**. Hence the dissociation of water is **endothermic** **[1m]**

.....[1]

(iv) Determine the pH of pure water at body temperature, 37 °C.

From Fig. 6.1, at 37 °C, $K_w = 2.4\times10^{-14}$ mol² dm⁻⁶ **[1m]**

$K_w = [H^+][OH^-] = 2.4\times10^{-14}\ mol^2\ dm^{-6}$

Since $[H^+] = [OH^-]$,

$[H^+]^2 = 2.4\times10^{-14}\ mol^2\ dm^{-6}$

$[H^+] = \sqrt{2.4\times10^{-14}} = \mathbf{1.5492\times10^{-7}\ mol\ dm^{-3}}$ **[1m]**

$pH = -\lg[H^+] = -\lg(1.5492\times10^{-7}) = 6.8099 \approx \mathbf{6.81}$ **[1m]**

[3]

(c) In humans it is important for blood to be maintained at a pH between 7.35 and 7.45. One of the way it does this is by using a buffer of CO_2(aq) and HCO_3^-(aq).

During vigorous exercise the muscles produce lactic acid. Lactic acid is transported by the blood to the liver to be broken down.

(i) State the effect that exercise will have on the pH of blood if there is no buffer present.

Since lactic acid is produced, the pH of blood will **decrease** **[1m]** .....[1]

(ii) Write equation(s) to explain how the CO_2(aq) / HCO_3^-(aq) buffer system helps to maintain the pH of blood between 7.35 and 7.45 during exercise.

The **conjugate base**, HCO_3^-, will react with H^+ from the lactic acid:

$$\mathbf{HCO_3^-(aq) + H^+(aq) \rightarrow H_2CO_3(aq) \rightarrow H_2O(\mathit{l}) + CO_2(aq)}$$ **[1m]**

removing the lactic acid **[1m]** produced in the muscle, thus maintaining the pH of blood.

.....[2]

For Examiner's Use

(c) Chlorine reacts with both propane and propene, but under different conditions.

Write equations, giving the structural formulae of the organic products, and state the conditions for the reaction of chlorine.

(i) with propane

$CH_3CH_2CH_3 + Cl_2(g) \xrightarrow{\text{uv light [1m]}} CH_3CH_2CH_2Cl + HCl$ **[1m]** ....[2]

(ii) with propene

$CH_3CH{=}CH_2 + Cl_2(g) \xrightarrow{\text{room temp [1m]}} CH_3CHClCH_2Cl$ **[1m]** ....[2]

[Total: 20]

For Examiner's Use

7 (a) In the presence of acid, $H^+(aq)$, aqueous bromate(V) ions, $BrO_3^-(aq)$, react with aqueous bromide ions, $Br^-(aq)$, to produce bromine, $Br_2(aq)$.

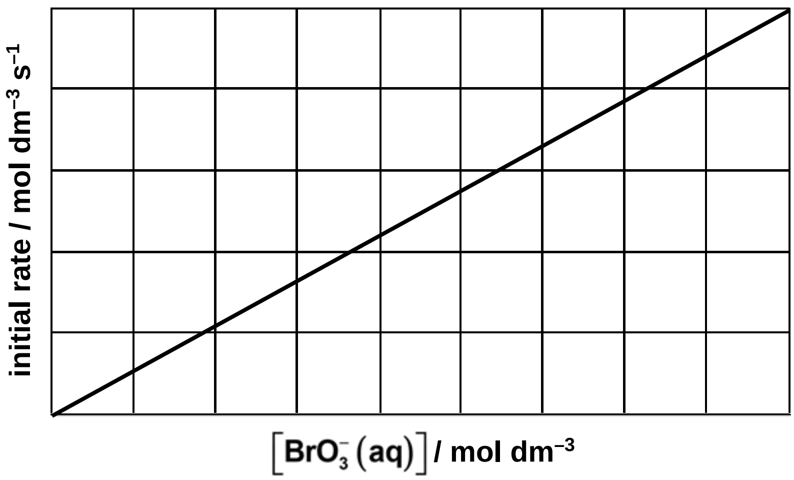
A student carried out an investigation into the kinetics of this reaction.

(i) Balance the ionic equation for this reaction.

BrO_3^- + ...5.... Br^- + ...6.... H^+ → ....3.... Br_2 + ...3... H_2O **[1m]** [1]

The student investigated how different concentrations of $BrO_3^-(aq)$ affect the initial rate of the reaction.

A graph of initial rate against $[BrO_3^-(aq)]$ is shown below.



The student then investigated how different concentrations of $Br^-(aq)$ and $H^+(aq)$ affect the initial rate of the reaction.

The results are shown below.

$[BrO_3^-(aq)]$ / mol dm^{-3}	$[Br^-(aq)]$ / mol dm^{-3}	$[H^+(aq)]$ / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
5.0×10^{-2}	1.5×10^{-1}	3.1×10^{-1}	1.19×10^{-5}
5.0×10^{-2}	3.0×10^{-1}	3.1×10^{-1}	2.38×10^{-5}
5.0×10^{-2}	1.5×10^{-1}	6.2×10^{-1}	4.76×10^{-5}

For Examiner's Use

(ii) Using the results from the student's experiments, determine the order of reactions with respect to all the three reactants.

Graph of initial rate against $[BrO_3^-(aq)]$:

Straight/diagonal line through origin thus is **1st order** with respect to BrO_3^-.

Using initial rates data:

When $[Br^-]$ is doubled, rate × 2 thus **1st order** with respect to Br^-

When $[H^+]$ × 2, rate × 4 (2^2) thus **2nd order** with respect to H^+

order w.r.t. BrO_3^- = ... **1 [1m]** ....

order w.r.t. Br^- = ... **1 [1m]** ....

order w.r.t. H^+ = ... **2 [1m]** ....[3]

(iii) Write the rate equation and calculate the rate constant for this reaction, including the units.

Rate equation is $\mathbf{rate = k[BrO_3^-][Br^-][H^+]^2}$ **[1m]**

Using the first set of data,

$$k = \frac{\text{rate}}{[BrO_3^-][Br^-][H^+]^2} = \frac{1.19\times10^{-5}}{(5.0\times10^{-2})(1.5\times10^{-1})(3.1\times10^{-1})^2}$$

$= 0.01651 \approx$ **0.0165 [1m] $\mathbf{mol^{-3}\ dm^{9}\ s^{-1}}$ [1m]**

[3]

(b) Sodium, magnesium, aluminium, silicon, phosphorus, sulfur, chlorine and neon are elements in period 3 of the periodic table.

(i) State and explain the differences between the ionic radii of Na^+, Si^{4+}, and P^{3-} and Cl^-.

The **anions have larger ionic radii than the cations** as the **anions have an extra quantum shell of electrons**. **[1m]**

Si^{4+} and Na^+ are **isoelectronic**, so are P^{3-} and Cl^-. But the **nuclear charge of Si is higher** than that of Na, and that of **Cl is higher** than that of P. Hence the **effective nuclear charge of Si^{4+} is higher than Na^+**, and that of **Cl^- is higher than P^{3-}**. Attraction of the electrons by the nucleus (protons) is greater, thus resulting in a smaller ionic radius for Si^{4+} and Cl^-. **[1m]** ....[2]

For Examiner's Use

(ii) Sodium, silicon, phosphorus and chlorine also differ greatly in their melting points. Describe how their melting points differ, and explain this variation.

The melting points of **Si > Na > P_4 > Cl_2**. **[1m]**

Si has a **giant covalent structure** with **strong covalent bonds** between the atoms. **[1m]** A lot of energy is required to break the strong covalent bonds, hence the very high melting point.

Na has **giant metallic structure**. Metallic bonds are **stronger than the dispersion forces** present in P_4 and Cl_2 and Na has higher melting point than the 2 non-metals. However, as Na has only 1 valence electron per atom, so the metallic bond is much **weaker than the covalent bonding** in silicon. **[1m]**

Dispersion forces strength is proportional to the number of electrons in the molecules. P_4 has more polarisable electron cloud than Cl_2, hence P has **higher melting point**. **[1m]** [4]

(iii) The acid-base behaviour of aluminium oxide, Al_2O_3, shows similarities to that of magnesium oxide, MgO, on the one hand, and phosphorus(V) oxide, P_4O_{10}, on the other.

Describe what these similarities are, and explain why aluminium oxide occupies this in-between position.

Write equations for all the reactions you choose to illustrate your answer.

Aluminium oxide is **both basic**, like magnesium oxide, **and acidic**, like phosphorus(V) oxide. **[1m]** It is amphoteric ('in-between position'). It is an ionic oxide with some covalent character.

Al^{3+} is a small and highly charged ion. Its **high charge density** gives it **great polarising power**. **[1m]** This results in the polarisation of the O^{2-} ion, giving the ionic bond between Al^{3+} and O^{2-} ions some **covalent character**. **[1m]**

Al_2O_3 shows its basic property when it reacts with acids, e.g. HCl

$$Al_2O_3(s) + 6HCl(aq) \rightarrow 2Al^{3+}(aq) + 6Cl^-(aq) + 3H_2O(l)$$ **[1m]**

Al_2O_3 shows its acidic property when it reacts with alkalis, e.g. NaOH

$$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2Na^+(aq) + 2Al(OH)_4^-(aq)$$ **[1m]**

[5]

For Examiner's Use

(c) Sodium borohydride, $NaBH_4$, is a useful reducing agent in organic chemistry. It reduces both propanal and propanone.

Write balanced equations, giving the structural formulae of the organic products, to illustrate its reducing property.

(i) with propanal

$CH_3CH_2CHO + 2[H] \xrightarrow{NaBH_4} CH_3CH_2CH_2OH$ **[1m]** ....[1]

(ii) with propanone

$CH_3COCH_3 + 2[H] \xrightarrow{NaBH_4} CH_3CH(OH)CH_3$ **[1m]** ....[1]

[Total: 20]