



Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

Model Answers

Forename(s)

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Candidate signature

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# AS CHEMISTRY

## Unit 2 Chemistry in Action

Friday 10 June 2016

Afternoon

Time allowed: 1 hour 45 minutes

### Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator.

### Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

### Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  - use good English
  - organise information clearly
  - use scientific terminology accurately.

### Advice

- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.



JUN16CHEM201

WMP/June16/E5

CHEM2

## Section A

Answer all questions in the spaces provided.

1 This question is about the Group 2 metals and their compounds.

1 (a) Explain why the first ionisation energy of barium is less than the first ionisation energy of calcium.

[2 marks]

As barium has more orbitals and the outer shell is therefore further away from the nucleus. This means there is less attraction between the nucleus and outer electrons.

1 (b) Magnesium reacts readily with steam.

State two observations you would make when magnesium reacts with steam. Write an equation for the reaction.

[3 marks]

Observation 1 white solid.

Observation 2 Bright white light

Equation  $Mg + H_2O \rightarrow MgO + H_2$



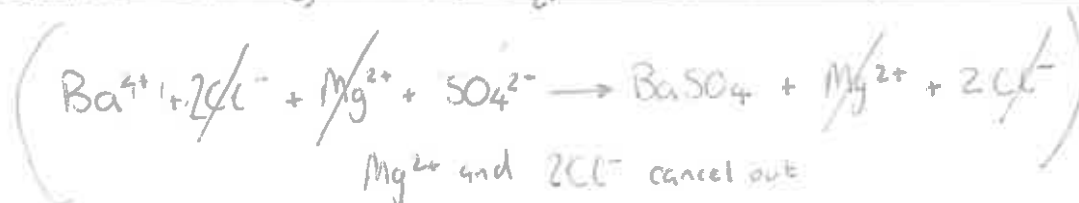
- 1 (c) Explain why different observations are made when aqueous barium chloride is added separately to aqueous magnesium sulfate and to aqueous magnesium nitrate.

Write the simplest ionic equation, including state symbols, for any reaction that occurs.

[2 marks]

Explanation BaSO<sub>4</sub> is insoluble but Ba(NO<sub>3</sub>)<sub>2</sub> is soluble, so you would get a white ppt with BaSO<sub>4</sub>.

Equation Ba<sup>2+</sup>(aq) + SO<sub>4</sub><sup>2-</sup>(aq) → BaSO<sub>4</sub>(s)



7

Turn over for the next question

Turn over ►



2 Standard enthalpy of combustion data can be used to calculate enthalpies of formation.

2 (a) State the meaning of the term standard enthalpy of combustion.

[3 marks]

The enthalpy change when 1 mol of a substance is reacts completely in oxygen when all reactants and products are in their standard states.

2 (b) The equation corresponding to the enthalpy of formation of propan-1-ol is shown.

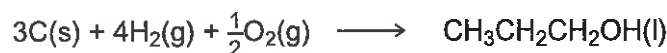


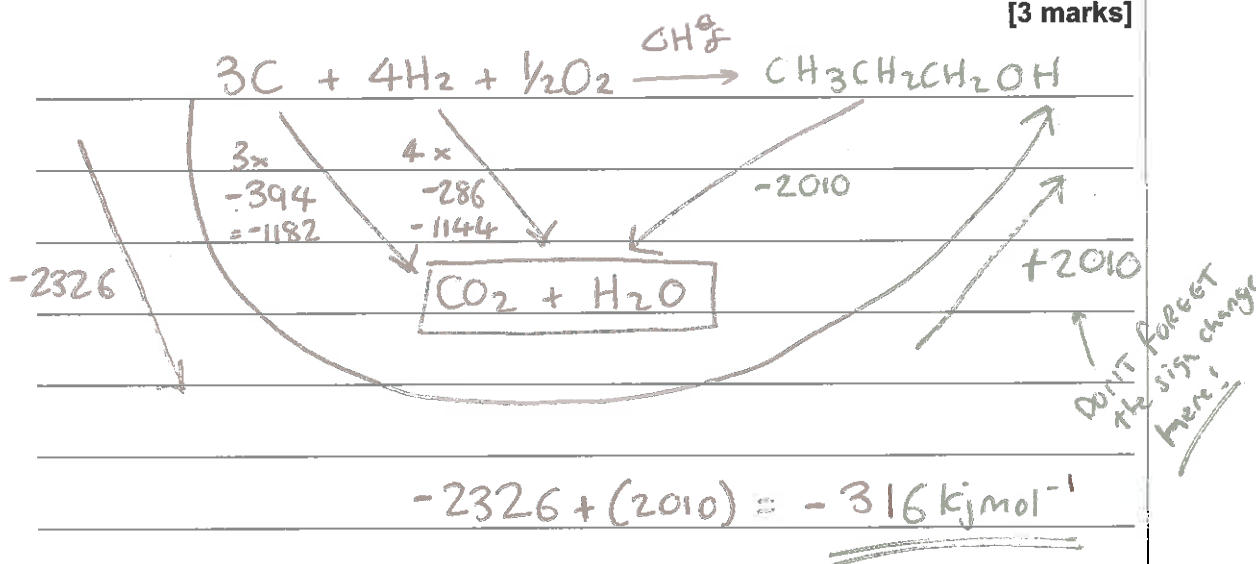
Table 1 contains some standard enthalpy of combustion data.

Table 1

	C(s)	H <sub>2</sub> (g)	CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> OH(l)
$\Delta H_c^\ominus / \text{kJ mol}^{-1}$	-394	-286	-2010

Use data from Table 1 to calculate a value for the standard enthalpy of formation of propan-1-ol. Show your working.

[3 marks]



2 (c) An equation for the complete combustion of gaseous propan-1-ol is shown.



Table 2 shows some bond enthalpy data.

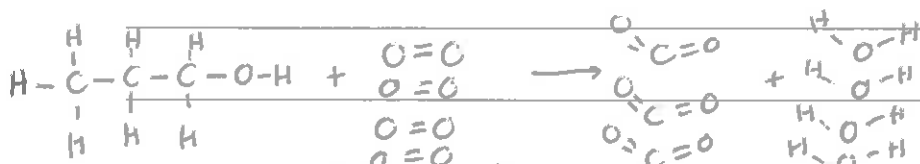
Table 2

	C-H	C-O	O-H	C=O	O=O
Bond enthalpy / kJ mol <sup>-1</sup>	412	360	463	805	496

Use data from Table 2 and the enthalpy change for this reaction to calculate a value for the bond enthalpy of a C-C bond in propan-1-ol.

[3 marks]

$$\Delta H = \sum \text{reactants} - \sum \text{products}$$



$$\begin{array}{l} 2 \times \text{C}-\text{C} = ? \quad (\frac{1}{2} \text{O}=\text{O}!!) \quad \rightarrow \quad 6 \times 805 \quad 8 \times 463 \\ 7 \times \text{C}-\text{H} = 2884 \quad 4\frac{1}{2} \times \text{O}=\text{O} = \quad = 4830 \quad = 3704 \\ 1 \times \text{C}-\text{O} = 360 \quad 2232 \\ 1 \times \text{O}-\text{H} = 463 \quad \underbrace{\hspace{10em}}_{8534} \\ \hline 5939 \end{array}$$

$$-1893 = ((2 \times \text{C}-\text{C}) + 5939) - 8534$$

$$0 = (2 \times \text{C}-\text{C}) - 2595 + 1893$$

Turn over for the next question

$$0 = (2 \times \text{C}-\text{C}) - 702$$

$$702 = 2 \times \text{C}-\text{C} \quad \frac{702}{2} = \text{C}-\text{C} \quad \text{C}-\text{C} = \underline{\underline{351}} \text{ kJ mol}^{-1}$$

*I always find these questions very long!! if you are getting a little confused come back to it later!*

Turn over ►



3 Haloalkanes are used as refrigerants, solvents and anaesthetics.

3 (a) Trichloromethane ( $\text{CHCl}_3$ ) is a haloalkane that can be formed by heating a mixture of chloromethane ( $\text{CH}_3\text{Cl}$ ) and chlorine.

3 (a) (i) Write an overall equation for the formation of trichloromethane by the reaction of chloromethane with chlorine.

[1 mark]



3 (a) (ii) Name the mechanism for this formation of trichloromethane.

[1 mark]

free radical substitution

3 (a) (iii) Dichloromethane ( $\text{CH}_2\text{Cl}_2$ ) is an intermediate in this formation of trichloromethane.

Write an equation for each of the following steps in the mechanism for the reaction of dichloromethane with chlorine.

[4 marks]

Initiation step



First propagation step



Second propagation step



A termination step leading to the formation of a compound with formula  $\text{C}_2\text{H}_2\text{Cl}_4$



Base all steps on heating  
towards  $\text{C}_2\text{H}_2\text{Cl}_4$ .



- 3 (b) Chlorotrifluoromethane ( $\text{CClF}_3$ ) is used as a refrigerant, but is being phased out due to concerns about ozone depletion in the upper atmosphere. In the upper atmosphere,  $\text{CClF}_3$  decomposes in the presence of UV light forming a reactive intermediate that catalyses the decomposition of ozone.

- 3 (b) (i) Write an equation to show how  $\text{CClF}_3$  decomposes to form the reactive intermediate. [1 mark]



- 3 (b) (ii) Write two equations to show how this reactive intermediate is involved in catalysing the decomposition of ozone. [2 marks]



they sometimes ask for the overall equation next which would be  
 $2\text{O}_3 \rightarrow 3\text{O}_2$  as the radicals cancel out!

Turn over for the next question

Turn over ►



4 Compounds **A**, **B**, **C** and **D** are isomers with the molecular formula  $C_4H_{10}O$ . They all have a broad absorption in their infrared spectra in the range  $3230-3550\text{ cm}^{-1}$ .

4 (a) Use **Table A on the data sheet** to identify the bond and the functional group present responsible for this absorption.

OH (alcohol) → MUST be specific as there is also OH(acid)! [1 mark]

4 (b) Compounds **A** and **B** are both straight-chain compounds.

**A** can be oxidised to form **P**.

**B** can be oxidised to form **Q**.

**P** and **Q** are isomers with molecular formula  $C_4H_8O$

Tollens' reagent and Fehling's solution can be used to distinguish between isomers **P** and **Q**. The results shown in **Table 3** are obtained.

**Table 3**

Compound	Observation with Tollens' reagent	Observation with Fehling's solution
<b>P</b>	No visible change	No visible change
<b>Q</b>	Silver mirror formed	Brick-red precipitate formed

Use the information about compounds **P** and **Q** to identify compounds **A** and **B**. Explain your answer with reference to the functional groups in **P** and **Q**.

[3 marks]

Identity of **A** Butan-2-ol

Identity of **B** Butan-1-ol

Explanation A is a 2° alcohol and therefore is oxidised to a ketone (Butanone, P) which cannot be further oxidised by tollens or fehling's. B is a 1° alcohol which is oxidised to an aldehyde (Butanal, Q) which is further oxidised to Butanoic acid and give a positive result with tollens / fehling's.





- 4 (c) Isomer **C** is resistant to oxidation.  
Isomer **C** reacts to form compound **R** that has an absorption in its infrared spectrum in the range  $1620\text{--}1680\text{ cm}^{-1}$ .

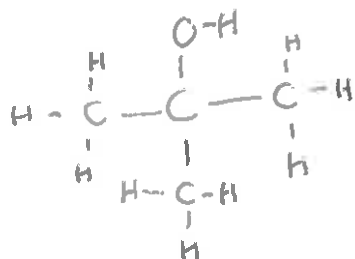
State the bond that causes the absorption in the range  $1620\text{--}1680\text{ cm}^{-1}$ .

Give the displayed formula of isomer **C**.

Identify the reagent and give **one** reaction condition needed to convert **C** into **R**.  
[4 marks]

Bond C=C

Displayed formula of **C**



For it to be resistant  
to oxidation (alcohol)  
It would have to be a  
3° alcohol!!!

Reagent H<sub>2</sub>SO<sub>4</sub> - Concentrated

Condition Reflux

Question 4 continues on the next page

Turn over ►



- 4 (d) Compound **D** is a branched-chain isomer that can be oxidised to form compounds **S** and **T**.
- 4 (d) (i) Compound **S** is obtained by distilling it off as it forms during the oxidation. Compound **T** is formed when the oxidation takes place under reflux.

Identify the functional groups in **S** and **T**.

Explain, with reference to intermolecular forces, why it is possible to obtain compound **S** but not **T** from the reaction mixture by distilling off **S** as soon as it forms.

[3 marks]

*S = aldehyde T = Carboxylic acid*

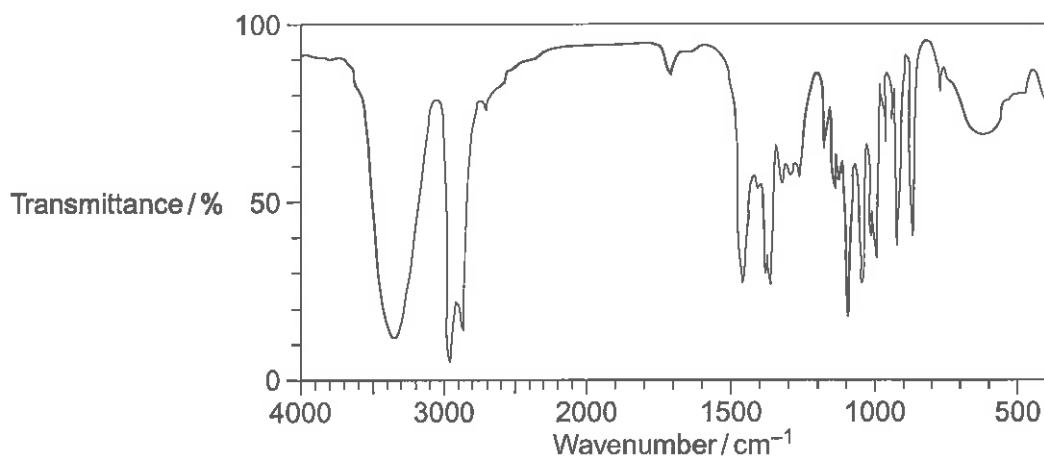
*T has a higher boiling point due to hydrogen bonding which are stronger intermolecular forces than those in the aldehyde.*

*This question is referring to partial ~~and~~ complete oxidation.*



- 4 (d) (ii) A student claims to have oxidised compound D.  
Figure 1 shows the infrared spectrum of the product obtained by the student.

Figure 1



Suggest two ways in which the spectrum shows that compound D has **not** been oxidised.

[2 marks]

The spectra shows an O-H (alcohol) peak and also has no C=O peak showing this is neither an aldehyde or carboxylic acid.

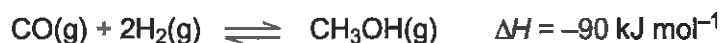
It is important to not only describe what is in the spectra but also what is NOT!

13

Turn over ►

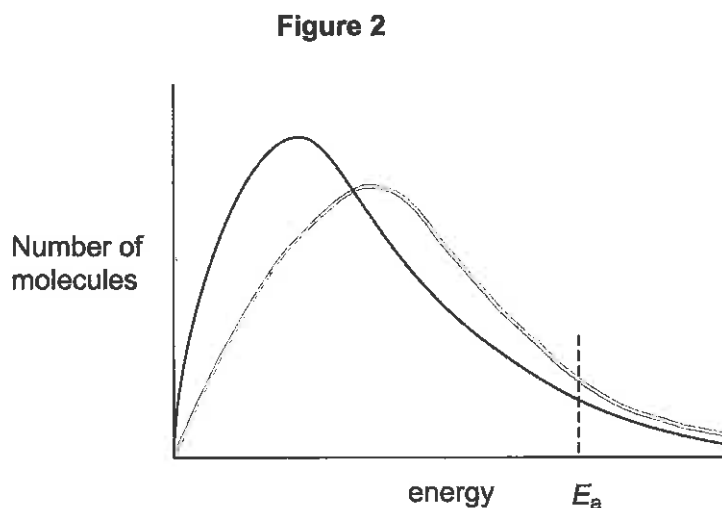


- 5 Methanol, for use as a fuel, can be produced by the reaction of carbon monoxide with hydrogen.



The reaction is typically carried out at 300 °C and  $3 \times 10^7$  Pa, in the presence of a catalyst.

- 5 (a) **Figure 2** shows the Maxwell–Boltzmann distribution for a mixture of carbon monoxide and hydrogen at 300 °C.



- 5 (a) (i) Sketch a second curve on **Figure 2** to show the distribution of molecular energies in this mixture at a higher temperature. [1 mark]
- 5 (a) (ii) Explain with reference to both curves in **Figure 2** how a small change in temperature leads to a large change in the rate of reaction. [2 marks]

The graph shows that more molecules have sufficient energy to react, the  $E_a$ , which would increase the numbers of successful collisions per second.



5 (b) Both the rate of production and equilibrium yield of methanol are considered when choosing the most appropriate conditions for the operation of this process on an industrial scale.

5 (b) (i) State and explain the effect of a higher pressure on the equilibrium yield of methanol.

[3 marks]

A higher pressure would increase the yield as there are less moles on the right so as pressure increases equilibrium position will shift right to counteract the change.

5 (b) (ii) By considering both rate and yield, state why the reaction is carried out at a temperature of 300 °C rather than at a higher temperature.

[2 marks]

The forward reaction is exothermic so an increase in temperature would lower the yield. However a high temp will speed up the time taken to reach equilibrium so a compromise between rate and yield is chosen.

8

Turn over for the next question

Turn over ►



6 The halogens are the elements in Group 7.

6 (a) The electronegativities of the halogens are shown in Table 4.

Table 4

Halogen	Fluorine	Chlorine	Bromine	Iodine
Electronegativity	4.0	3.0	2.8	2.5

Explain the trend in electronegativities shown by the halogens.

[2 marks]

As you go down the group atomic radius increases meaning more electron shells. The outer electrons and hence bonding pair of electrons are not as attracted to the positive nucleus.

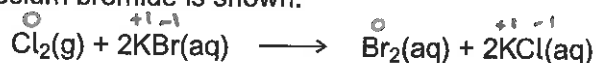
6 (b) The halogens can all behave as oxidising agents in reactions.

6 (b) (i) Explain, in terms of electron transfer, the meaning of the term oxidising agent.

[1 mark]

An electron acceptor.

6 (b) (ii) An equation for the reaction that takes place when chlorine gas is bubbled through aqueous potassium bromide is shown.



Explain, with reference to the oxidation states, why this is a redox reaction.

[1 mark]

ox state of Cl goes from 0 → -1

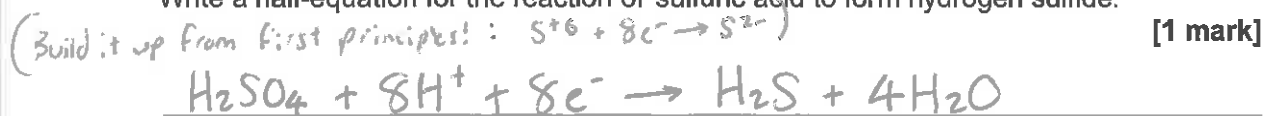
ox state of Br goes from -1 → 0.



6 (c) Solid sodium halides react with concentrated sulfuric acid.

6 (c) (i) A sample of solid sodium iodide is reacted with concentrated sulfuric acid. A black solid forms and hydrogen sulfide gas is produced.

Write a half-equation for the reaction of sulfuric acid to form hydrogen sulfide.



6 (c) (ii) Write a half-equation for the formation of the black solid.

[1 mark]



6 (c) (iii) Use your answers to parts (c) (i) and (c) (ii) to write an overall equation for the reaction of sodium iodide with concentrated sulfuric acid.

Remember to balance out the electrons too cancel them out.

[1 mark]



6 (c) (iv) Give the role of sulfuric acid in its reaction with sodium iodide.

Tick (✓) one box.

[1 mark]

Acid

Oxidising agent

Reducing agent

Electrophile

6 (c) (v) Write an equation for the reaction of concentrated sulfuric acid with solid sodium fluoride.

[1 mark]



6 (c) (vi) Suggest one reason why the reaction of sodium fluoride with concentrated sulfuric acid is different from the reaction with sodium iodide.

[1 mark]

Fluoride is a less powerful reducing agent.

Turn over ►



6 (d) Chlorine reacts with water to form an equilibrium mixture containing hydrochloric acid and chloric(I) acid.

6 (d) (i) Write an equation for the formation of this equilibrium mixture.

[1 mark]



6 (d) (ii) Household bleach contains sodium chlorate(I) and sodium chloride. State and explain, with reference to your equation in part (d)(i), why it is dangerous to acidify an aqueous mixture of sodium chlorate(I) and sodium chloride.

[2 marks]

The equilibrium would shift left when acid added producing toxic chlorine gas.

HCl is an acid so any H<sup>+</sup> would shift eq. left.





7 The ores used for the extraction of many metals contain metal sulfides or metal oxides. Various methods are used to extract metals from these ores.

7 (a) Sulfide ores such as zinc blende (ZnS) are crushed and then roasted in a stream of air to convert them into the metal oxide.

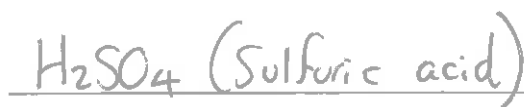
7 (a) (i) Write an equation for the reaction that takes place when ZnS is roasted in air.

[1 mark]



7 (a) (ii) State a useful substance that can be manufactured from the gaseous product of this reaction.

[1 mark]



(Contact process)

7 (b) Zinc oxide is reduced by carbon monoxide in the extraction of zinc. The carbon monoxide is produced by the incomplete combustion of methane.

7 (b) (i) Write an equation for the production of carbon monoxide by the incomplete combustion of methane.

[1 mark]



if this ever comes up then just use the carbon product they choose do not add C or CO<sub>2</sub> as well!!

7 (b) (ii) Write an equation for the reaction between zinc oxide and carbon monoxide.

[1 mark]



7 (c) Most copper is produced by reduction of copper(II) oxide with carbon. The copper(II) oxide is produced by roasting chalcopyrite (CuFeS<sub>2</sub>) in air.

Copper can also be obtained from other low-grade ores. When these low-grade ores are processed, aqueous solutions containing low concentrations of Cu<sup>2+</sup> ions are produced. Scrap iron is used to recover copper from these solutions.

7 (c) (i) Give the ionic equation for the reaction involved in the recovery of solid copper from an aqueous solution using scrap iron. Include state symbols.

[1 mark]



Turn over ►



- 7 (c) (ii) Suggest two environmental reasons and one economic reason why the extraction of copper from solutions containing  $\text{Cu}^{2+}$  ions, using iron, is preferable to the reduction of copper(II) oxide made by roasting chalcopyrite.

[3 marks]

Environmental reason 1 No greenhouse gases produced from the process (CO<sub>2</sub>).

Environmental reason 2 No SO<sub>2</sub> produced so no acid rain.

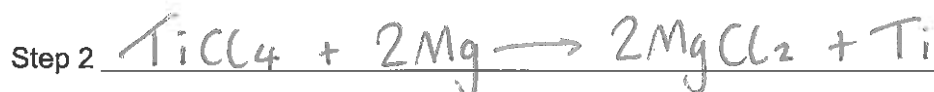
Economic reason less energy used therefore cheaper.

Not just  
cheaper!!  
↓

- 7 (d) Titanium can be extracted from its ore, rutile ( $\text{TiO}_2$ ), in a two-step process using carbon, chlorine and magnesium. Extraction of titanium is not possible by direct reduction of  $\text{TiO}_2$  with carbon.

- 7 (d) (i) Give equations for the two-step process using carbon, chlorine and magnesium.

[2 marks]



- 7 (d) (ii) State why direct reduction of  $\text{TiO}_2$  with carbon cannot be used.

[1 mark]

forms titanium carbide which makes it brittle.



**Turn over for the next question**

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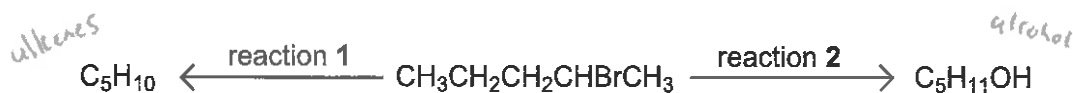
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## Section B

Answer all questions in the spaces provided.

- 8 Two reactions of 2-bromopentane, (CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>CHBrCH<sub>3</sub>) are shown.



The C<sub>5</sub>H<sub>10</sub> formed in reaction 1 exists as a mixture of three isomers, one of which is pent-1-ene. Two of the isomers are a pair of stereoisomers. All three isomers decolourise bromine.

- 8 (a) The same reagent is used in both reactions. The product is determined by the choice of conditions.

State the reagent and the conditions for each of reaction 1 and reaction 2.

State the role of the reagent in each reaction.

Name and outline the mechanism of reaction 1 for the formation of pent-1-ene.

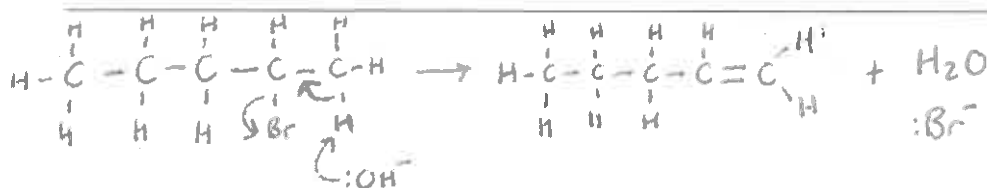
[8 marks]

Reagent used: NaOH.

Reaction 1 conditions: ethanolic. Reagent role: Base.

Reaction 2 conditions: aqueous. Reagent role: Nucleophile.

Mechanism for R<sub>x</sub>1: Elimination.



Reaction 1 forms alkenes → 3 isomers } Pent-1-ene  
 Reaction 2 forms alcohols. } E-pent-2-ene  
 } Z-pent-2-ene



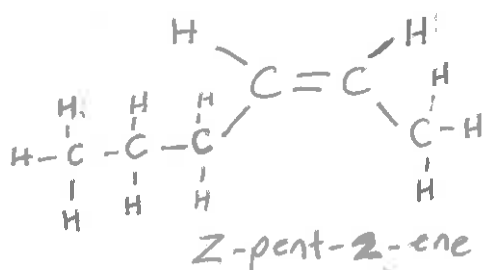
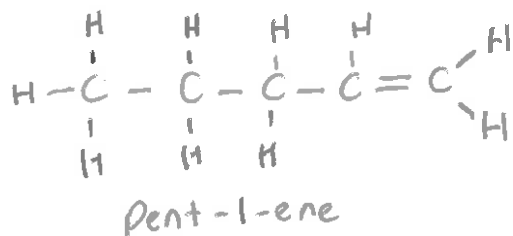
8 (b) All three isomers of  $C_5H_{10}$  contain the same functional group.

Draw the displayed formula of pent-1-ene. ✓

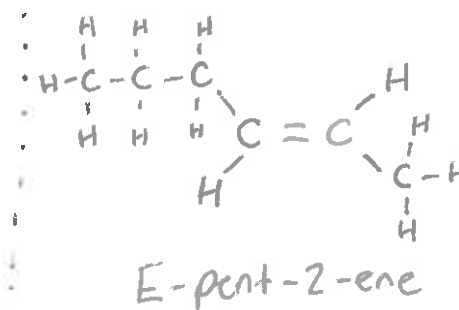
Draw the structures of the pair of stereoisomers and give their full IUPAC names.

Explain the origin of the stereoisomerism shown.

[5 marks]



(On Zcc same side!)



The stereoisomers occur as there is limited rotation around the C=C double bond and if there are two different groups on each end of C=C bond then Z, E isomers arise.

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Turn over ►



- 8 (c) The rates of hydrolysis of two chloroalkanes can be investigated by adding aqueous silver nitrate to the chloroalkanes. During the hydrolysis reactions, chloride ions are liberated slowly. Precipitates of silver chloride are formed.

Outline a method to compare the rate of hydrolysis of 1-chlorobutane with that of 2-chlorobutane. State how the method would ensure a fair test.

[4 marks]

Add  $\text{AgNO}_3$  solution to to samples of 1-chlorobutane and 2-chlorobutane in a beaker, ensuring that the same volume of each is used. Also ensure as many variables are controlled as possible such as temperature and concentrations. Record the time taken for a cross (under beaker) to be obscured for each. The less time taken the higher the rate.

This may remind you  
of the sodium thiosulfate  
cross experiment - the method  
is essentially the same.



**Turn over for the next question**

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9 Alcohols can be prepared from alkenes in various ways.

9 (a) On a laboratory scale, a mixture of propan-1-ol and propan-2-ol can be prepared from propene in two steps.

In step 1, propene reacts with cold, concentrated sulfuric acid to form intermediate compounds.

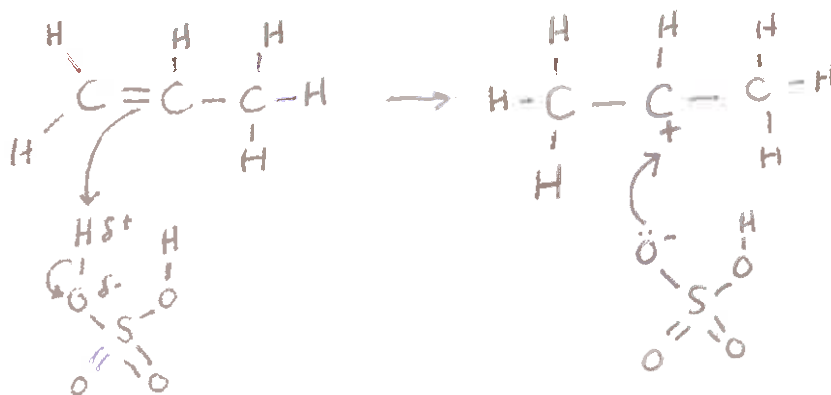
In step 2, the intermediate compounds react with water to form the mixture of alcohols.

Name and outline the mechanism for the reaction between propene and concentrated sulfuric acid to form the intermediate compound which gives propan-2-ol in step 2.

Explain why propan-2-ol is the major product of this preparation.

Electrophilic  
Addition

[7 marks]



Don't have to  
show over!!  
product.

2° = secondary  
1° = primary.

Propan-2-ol is the major product as the carbocation formed above is 2° which is more stable than the 1° alternative.





- 9 (b) On an industrial scale ethanol can be produced from ethene by direct hydration or from glucose by fermentation.

State the conditions for the direct hydration reaction.

State two advantages and two disadvantages of the fermentation method compared with the direct hydration method.

[6 marks]

Direct hydration requires a high temperature and high pressure with a phosphoric acid catalyst.

fermentation advantages: Much lower temp and pressures therefore cheaper and also uses renewable and sustainable resources.

fermentation disadvantages: Much slower and produces an impure product that will then need to be purified.

END OF QUESTIONS

13

A common question  
so make sure you know  
this one!



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