



## Cambridge International AS & A Level

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NAME

CENTRE  
NUMBER

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**CHEMISTRY**

**9701/22**

Paper 2 AS Level Structured Questions

**February/March 2020**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: Data booklet

### INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.

### INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Blank pages are indicated.



Answer **all** the questions in the spaces provided.

1 Group 2 metals form alkaline solutions in water.

(a) (i) Write the equation for the reaction of calcium oxide with water.

..... [1]

(ii) Identify the ion that causes an aqueous solution to be alkaline.

..... [1]

(b) The table shows the melting points of some Group 2 metal oxides.

compound	melting point/°C
MgO	2825
CaO	2613
SrO	2531
BaO	1923

Explain the trend in the melting points of the oxides down Group 2.

.....  
 .....  
 ..... [2]

(c) Oxygen reacts readily with some metals, but each Group 2 metal requires strong heating to start the reaction with oxygen.

Suggest why strong heating is required to start these reactions.

.....  
 ..... [1]

(d) Beryllium oxide reacts with hydrochloric acid to form molecules of  $\text{BeCl}_2$ .

Deduce the bond angle in  $\text{BeCl}_2$ .

..... [1]

## 3

(e) Unlike the other oxides of Group 2 metals, beryllium oxide is amphoteric.

(i) Give the meaning of the term *amphoteric*.

.....  
 ..... [1]

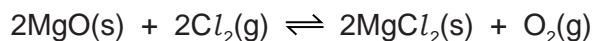
(ii) Beryllium oxide and aluminium oxide have similar chemical properties.

The  $\text{Be}(\text{OH})_4^{2-}$  anion is a product of the reaction between beryllium oxide and excess concentrated  $\text{OH}^-(\text{aq})$ .

Construct an equation for this reaction.

..... [1]

(f) Magnesium oxide reacts reversibly with chlorine according to the following equation.



Under certain conditions, a dynamic equilibrium is established.

(i) State **two** features of a reaction that is in dynamic equilibrium.

1 .....  
 2 ..... [2]

(ii) The equilibrium constant,  $K_p$ , is given by the following expression.

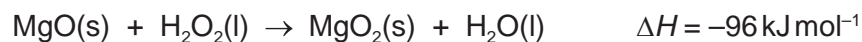
$$K_p = \frac{p_{\text{O}_2}}{p_{\text{Cl}_2}^2}$$

At  $1.00 \times 10^5 \text{ Pa}$  and  $500 \text{ K}$ , 70% of the initial amount of  $\text{Cl}_2(\text{g})$  has reacted.

Calculate  $K_p$  and state its units.

$K_p =$  .....  
 units = ..... [3]

(g) Magnesium peroxide,  $\text{MgO}_2$ , is made in the following reaction.



compound	enthalpy change of formation, $\Delta H_f / \text{kJ mol}^{-1}$
MgO(s)	-602
H <sub>2</sub> O <sub>2</sub> (l)	-188
H <sub>2</sub> O(l)	-286

(i) The peroxide ion is  $\text{O}_2^{2-}$ .

Deduce the average oxidation number of oxygen in the peroxide ion.

..... [1]

(ii) Define the term *enthalpy change of formation*.

.....  
 .....  
 ..... [2]

(iii) Use the data given to calculate the enthalpy change of formation of  $\text{MgO}_2(\text{s})$ .

$\Delta H_f \text{ MgO}_2(\text{s}) = \dots\dots\dots \text{ kJ mol}^{-1}$  [2]

## 5

- (iv) Magnesium peroxide decomposes slowly to form magnesium oxide and oxygen.



Use your answer to (g)(iii) and the data in the table to calculate the enthalpy change of this reaction.

*If you were unable to obtain an answer to (g)(iii), use the value  $\Delta H_f = -550 \text{ kJ mol}^{-1}$ . This is **not** the correct answer.*

enthalpy change of reaction = .....  $\text{kJ mol}^{-1}$  [1]

[Total: 19]

2 The Group 17 elements, chlorine, bromine and iodine, are non-metals that show trends in their physical and chemical properties.

(a) Describe the trend in the colour of the Group 17 elements down the group.

.....  
..... [1]

(b) The Group 17 elements can oxidise many metals to form halides.

(i) Describe the relative reactivity of the elements in Group 17 as oxidising agents.

.....  
..... [1]

(ii) Chlorine reacts with hot tin metal to form tin(IV) chloride,  $\text{SnCl}_4$ .

$\text{SnCl}_4$  is a colourless liquid at room temperature that reacts vigorously with water to form an acidic solution.

Suggest the type of structure and bonding shown by  $\text{SnCl}_4$ . Explain your answer.

.....  
.....  
.....  
.....  
..... [2]

(c) The Group 17 elements form soluble halides with sodium.

(i) Describe what is seen when dilute  $\text{AgNO}_3(\text{aq})$  is added to  $\text{NaBr}(\text{aq})$  followed by aqueous ammonia.

.....  
.....  
..... [2]

7

- (ii)  $\text{NaCl}$  reacts with concentrated  $\text{H}_2\text{SO}_4$  to form  $\text{HCl}$  and  $\text{NaHSO}_4$ .

Explain the difference between the reactions of concentrated  $\text{H}_2\text{SO}_4$  with  $\text{NaCl}$  and with  $\text{NaI}$ . Your answer should refer to the role of the sulfuric acid in each reaction.

.....

.....

.....

.....

.....

.....

..... [3]

- (d) The hydrogen halides are useful reagents in organic and inorganic reactions.

- (i) Describe and explain the trend in the boiling points of the hydrogen halides,  $\text{HCl}$ ,  $\text{HBr}$  and  $\text{HI}$ .

.....

.....

.....

..... [2]

- (ii) Describe and explain the trend in the thermal stabilities of the hydrogen halides,  $\text{HCl}$ ,  $\text{HBr}$  and  $\text{HI}$ .

.....

.....

.....

..... [2]

- (e) Lucas's reagent is a mixture of  $\text{HCl}$  and  $\text{ZnCl}_2$ . Primary, secondary and tertiary alcohols can be distinguished by their reaction with Lucas's reagent.

Alcohols react with the  $\text{HCl}$  in Lucas's reagent to form halogenoalkanes.

$\text{ZnCl}_2$  acts as a homogeneous catalyst for these reactions.

- (i) Explain the meaning of the term *homogeneous*.

.....  
 ..... [1]

- (ii) Pentan-3-ol,  $\text{C}_2\text{H}_5\text{CH}(\text{OH})\text{C}_2\text{H}_5$ , reacts slowly with  $\text{HCl}$  to form a secondary halogenoalkane.

Complete the equation for this reaction using structural formulae.

$\text{C}_2\text{H}_5\text{CH}(\text{OH})\text{C}_2\text{H}_5 + \dots\dots\dots$  [1]

- (iii) The fastest reaction shown by Lucas's reagent is with a tertiary alcohol.

Draw the structure of the tertiary alcohol that is an isomer of pentan-3-ol.

[1]

- (iv) Tertiary alcohols tend to react with Lucas's reagent using the same mechanism as in their reaction with  $\text{HCl}$ .

Suggest the type of reaction shown by tertiary alcohols with Lucas's reagent.

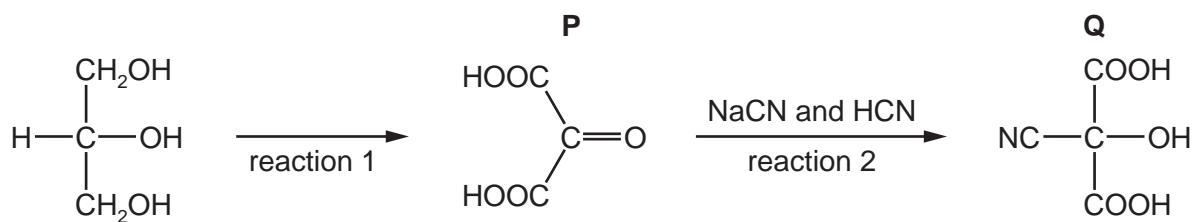
..... [1]

[Total: 17]



3 Glycerol,  $\text{CH}_2(\text{OH})\text{CH}(\text{OH})\text{CH}_2\text{OH}$ , is widely used in the food industry and in pharmaceuticals.

(a) A series of reactions starting from glycerol is shown.



(i) Suggest the reagent(s) and conditions for reaction 1.

.....  
 ..... [2]

(ii) Name the reaction mechanism for reaction 2.

..... [1]

(iii) Give the observation you would make when 2,4-dinitrophenylhydrazine is added to **P**.

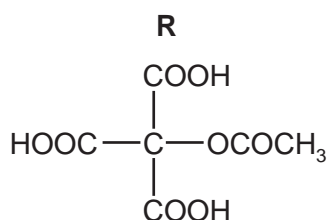
..... [1]

(iv) **Q** does **not** show optical isomerism.

Explain why.

.....  
 .....  
 .....  
 ..... [1]

(v) When **Q** is heated with excess aqueous ethanoic acid in the presence of a catalytic amount of sulfuric acid, two reactions take place to form compound **R**.



Identify the two types of reaction that occur.

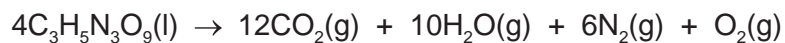
1 .....

2 .....

[2]

**(b)** Glycerol can be used as a starting material in the manufacture of nitroglycerine,  $C_3H_5N_3O_9$ .

Nitroglycerine decomposes rapidly on heating to form a mixture of gases.



A sample of nitroglycerine decomposes, releasing  $1.06 \text{ dm}^3$  of  $O_2(g)$  at  $850 \text{ K}$  and  $1.00 \times 10^5 \text{ Pa}$ .

**(i)** Calculate the mass of nitroglycerine that decomposes.

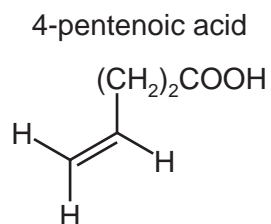
mass of nitroglycerine = ..... g [3]

**(ii)** Calculate the total volume of gas released by this decomposition at  $850 \text{ K}$  and  $1.00 \times 10^5 \text{ Pa}$ .

total volume of gas = .....  $\text{dm}^3$  [1]

(c) Fats are compounds made from glycerol and unsaturated carboxylic acids.

4-pentenoic acid is an example of an unsaturated carboxylic acid.



(i) Give the molecular formula of 4-pentenoic acid.

..... [1]

(ii) Draw the repeat unit of the addition polymer that can be formed from 4-pentenoic acid.

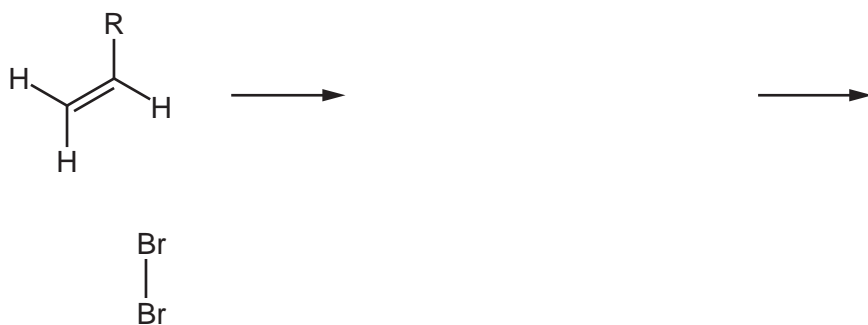
[1]

(iii) Unsaturated acids are often brominated before being added to soft drinks.

Complete the mechanism for the addition of  $\text{Br}_2$  to 4-pentenoic acid.

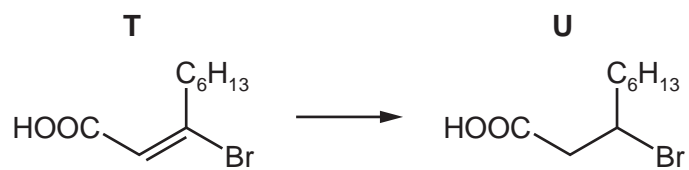
- Include the structures of the intermediate and the product of the reaction.
- Include all charges, partial charges, lone pairs and curly arrows.

In the mechanism, R has been used to represent  $(\text{CH}_2)_2\text{COOH}$ .



[4]

(d) A reaction of another unsaturated carboxylic acid, **T**, is shown.



(i) **T** is one of a pair of geometrical (*cis-trans*) isomers.

Draw the other geometrical isomer of **T** and explain why the molecules exhibit this form of isomerism.

.....  
 .....  
 ..... [3]

(ii) Identify the reagent used to convert **T** to **U**.

..... [1]

- (iii) The C–Br bond has an absorption between  $500\text{ cm}^{-1}$  and  $600\text{ cm}^{-1}$  in an infrared spectrum.

The infrared spectra for both **T** and **U** have absorptions between  $2850\text{ cm}^{-1}$  and  $2950\text{ cm}^{-1}$ . These correspond to C–H bonds.

Identify:

- two other absorptions that would be seen in the infrared spectra of both **T** and **U**
- one other absorption that would **only** be seen in the infrared spectrum of **T**.

For each absorption, give the range of the absorption and the bonds that correspond to these absorptions.

absorption 1 present in both spectra .....

.....

.....

absorption 2 present in both spectra .....

.....

.....

absorption **only** present in spectrum of **T** .....

.....

.....

[3]

[Total: 24]





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