



CANDIDATE
NAME

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CENTRE
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NUMBER

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9701/22

February/March 2020

1 hour 15 minutes

You must answer on the question paper.

You will need: Data booklet

- 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.

- 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 BeCl_2 .

Deduce the bond angle in BeCl_2 .

..... [1]

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

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

.....
 [1]

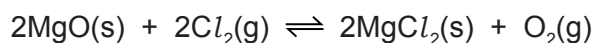
(ii) Beryllium oxide and aluminium oxide have similar chemical properties.

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.

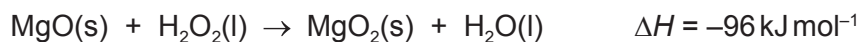
$$K_p = \frac{p_{\text{O}_2}}{p_{\text{Cl}_2}^2}$$

At $1.00 \times 10^5 \text{ Pa}$ and 500 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, MgO_2 , is made in the following reaction.



compound	enthalpy change of formation, $\Delta H_f / \text{kJ mol}^{-1}$
MgO(s)	-602
$\text{H}_2\text{O}_2(\text{l})$	-188
$\text{H}_2\text{O(l)}$	-286

(i) The peroxide ion is 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]

- (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 = 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, SnCl_4 .

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 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]

- (ii) NaCl reacts with concentrated H_2SO_4 to form HCl and NaHSO_4 .

Explain the difference between the reactions of concentrated H_2SO_4 with NaCl and with 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, HCl , HBr and HI .

.....

.....

.....

..... [2]

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

.....

.....

.....

..... [2]

- (e) Lucas's reagent is a mixture of HCl and ZnCl_2 . Primary, secondary and tertiary alcohols can be distinguished by their reaction with Lucas's reagent.

Alcohols react with the HCl in Lucas's reagent to form halogenoalkanes.

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 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 HCl .

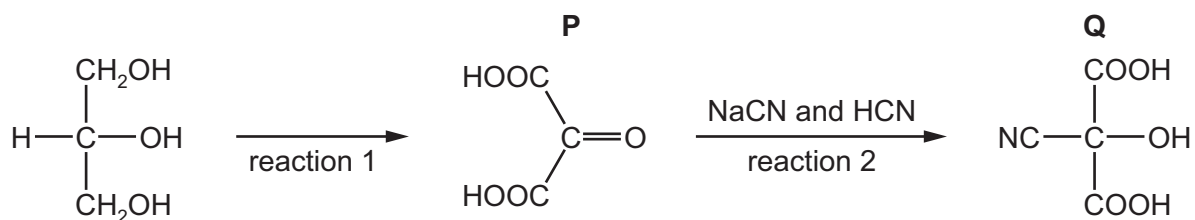
Suggest the type of reaction shown by tertiary alcohols with Lucas's reagent.

..... [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]

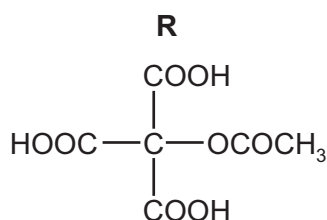
(iv) **Q** does **not** show optical isomerism.

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.

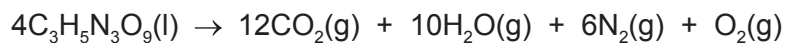
1

2

[2]

- (b) Glycerol can be used as a starting material in the manufacture of nitroglycerine, $\text{C}_3\text{H}_5\text{N}_3\text{O}_9$.

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



A sample of nitroglycerine decomposes, releasing 1.06 dm^3 of $\text{O}_2(\text{g})$ at 850 K and $1.00 \times 10^5 \text{ Pa}$.

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

mass of nitroglycerine = g [3]

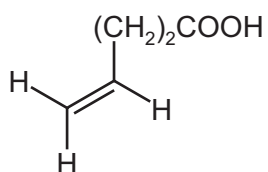
- (ii) Calculate the total volume of gas released by this decomposition at 850 K and $1.00 \times 10^5 \text{ Pa}$.

total volume of gas = 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.

4-pentenoic 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.

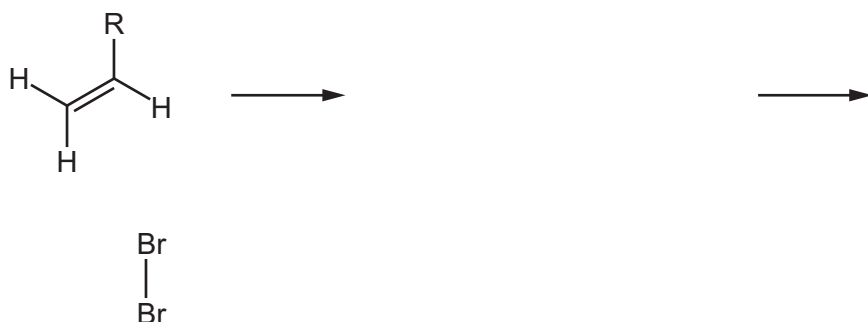
[1]

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

Complete the mechanism for the addition of Br_2 to 4-pentenoic acid.

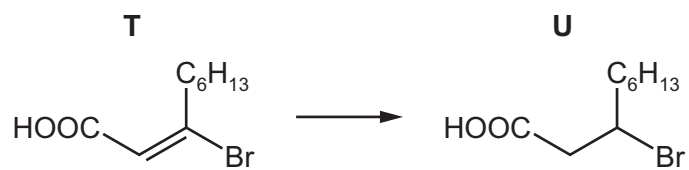
- Include the structures of the intermediate and the product of the reaction.
- Include all charges, partial charges, lone pairs and curly arrows.

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 cm^{-1} and 600 cm^{-1} in an infrared spectrum.

The infrared spectra for both **T** and **U** have absorptions between 2850 cm^{-1} and 2950 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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