Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

*5348916287*

**CHEMISTRY** **9701/21**

Paper 2 AS Level Structured Questions **May/June 2021**

**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 **12** pages. Any blank pages are indicated.




**[Turn over**

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

**1** Ethanedioic acid, $HO_2CCO_2H$, has a relative molecular mass of 90.0.

**(a) (i)** Explain what is meant by the term *relative molecular mass*.

.....

.....

..... [2]

**(ii)** State the empirical formula of ethanedioic acid.

..... [1]

**(iii)** Calculate how many atoms of carbon are present in 0.18 g of ethanedioic acid, $HO_2CCO_2H$.

Show your working.

atoms of carbon present = ..... [3]

**(b)** Solid ethanedioic acid reacts with aqueous calcium ions to make a precipitate of calcium ethanedioate, $CaC_2O_4$.

$CaC_2O_4$ breaks down when heated to form calcium oxide, carbon dioxide and carbon monoxide.

**(i)** Construct an equation to represent the reaction of $CaC_2O_4$ when heated. Include state symbols.

..... [2]

**(ii)** Identify the type of reaction which occurs when $CaC_2O_4$ is heated.

..... [1]

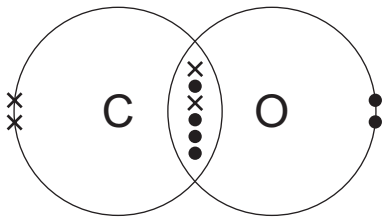
**(iii)** Identify another compound containing calcium ions which will also produce carbon dioxide and calcium oxide when it is heated.

..... [1]

[Total: 10]

**2** Carbon monoxide gas, CO(g), and nitrogen gas, $N_2(g)$, are both diatomic molecules.

**(a)** The diagram shows the arrangement of outer electrons in a molecule of CO(g).




**(i)** State **one** similarity and **one** difference in the way the atoms in a carbon monoxide molecule are bonded together compared to the atoms in a nitrogen molecule.

.....

.....

..... [2]

**(ii)** The table states the electronegativity values of carbon, nitrogen and oxygen atoms.

| | C | N | O |
|---|---|---|---|
| electronegativity | 2.5 | 3.0 | 3.5 |

Use the electronegativity values and relevant details from the *Data Booklet* to complete the table below.

| | $N_2$ | CO |
|---|---|---|
| number of electrons per molecule | | |
| type(s) of intermolecular (van der Waals') force | | |

[2]

**(b)** $N_2(g)$ is less reactive than CO(g) even though $N_2(g)$ has a lower bond energy than CO(g).

Suggest why CO(g) is more reactive than $N_2(g)$.

.....

..... [1]



**[Turn over**

**(c)** Both carbon monoxide and nitrogen are gases at room temperature and pressure.

They both behave like ideal gases under certain conditions.

**(i)** State the **two** conditions necessary for these two gases to approach ideal gas behaviour.

.....

..... [1]

**(ii)** Explain why $N_2(g)$ behaves more like an ideal gas than CO(g) does at 20.0 °C and 101 kPa.

.....

.....

..... [2]

**(d)** Calculate the amount, in mol, of pure nitrogen gas which occupies 100 $cm^3$ at 101 kPa and 20.0 °C.

Use relevant information from the *Data Booklet*. Show your working.

Assume nitrogen behaves as an ideal gas.

..... mol
[3]

[Total: 11]

**3** Sodium halide salts react with concentrated sulfuric acid at room temperature.

**(a) (i)** Write an equation to represent the reaction of NaC$l$(s) with concentrated sulfuric acid.

..... [1]

**(ii)** Name this type of reaction.

..... [1]

**(b)** NaI(s) reacts with concentrated sulfuric acid, at room temperature, to form steamy fumes.

**(i)** Identify the chemical responsible for the steamy fumes.

..... [1]

**(ii)** The reaction of NaI(s) with concentrated sulfuric acid continues, forming several other products, including a dark grey solid.

Identify the chemical responsible for the dark grey solid and **one** other product of this further reaction.

dark grey solid .....

other product .....

[2]

**(c)** Explain the differences in observations, at room temperature, when NaI(s) reacts with concentrated sulfuric acid compared to those for NaC$l$(s).

.....

.....

..... [2]

**(d)** Complete the equation for the reaction of $Br^-$ with excess concentrated $H_2SO_4$ at room temperature.

.....$Br^-$ + .....$H^+$ + .....$H_2SO_4$ $\rightarrow$ .....

[1]

[Total: 8]

**4** Aqueous bromine reacts with methanoic acid to form hydrogen bromide and carbon dioxide gas.

$$Br_2(aq) + HCO_2H(aq) \rightarrow 2HBr(aq) + CO_2(g)$$

The table shows the oxidation numbers of bromine and carbon in the species involved in this reaction.

| | Br in $Br_2$ | C in $HCO_2H$ | Br in HBr | C in $CO_2$ |
|---|---|---|---|---|
| oxidation number | 0 | +2 | –1 | +4 |

**(a)** Identify the oxidising agent in this reaction. Explain your reasoning with reference to oxidation numbers.

.....

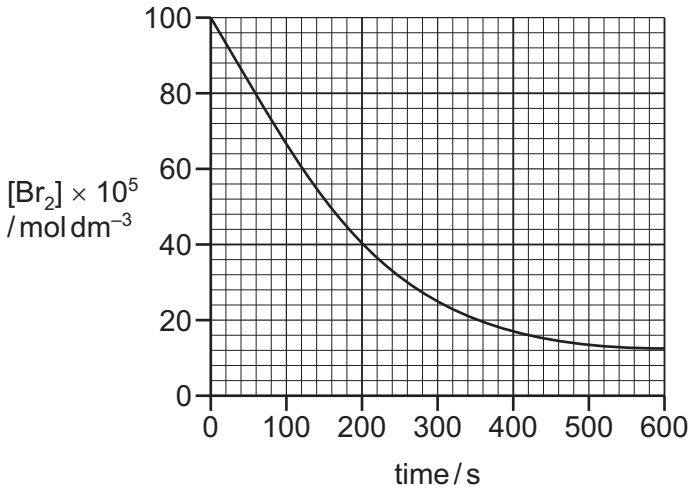
..... [1]

**(b)** Suggest one change you would observe, ignoring temperature changes, when bromine reacts with methanoic acid.

..... [1]

**(c)** This reaction can be followed by measuring the concentration of bromine present in the mixture at regular time intervals.

The graph shows the change in concentration of bromine against time in a reaction carried out at 20 °C.




**(i)** Use the graph to calculate the average rate of reaction at 20 °C during the first 600 s. State the units of this rate of reaction.

average rate of reaction ..... units .....

[2]

The experiment is repeated at a temperature of 40 °C. This relatively small increase in temperature produces a large increase in reaction rate.

**(ii)** Sketch a graph, on the same axes, to show the expected results when repeating the experiment at 40 °C. [1]

**(iii)** The rate of reaction increases when the frequency of successful collisions between reactant particles increases.

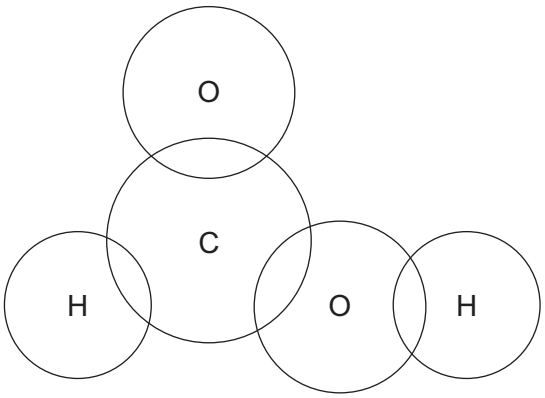
Explain why an increase in temperature produces this effect.

.....

.....

..... [2]

**(d)** Complete the 'dot-and-cross' diagram, showing outer electrons only, to show the bonding in methanoic acid, $HCO_2H$.




[2]

[Total: 9]

**5** **(a)** Naphtha is a mixture which contains only hydrocarbon molecules.

**(i)** What is meant by the term *hydrocarbon*?

.....

..... [1]

**(ii)** Name the raw material that is used to produce a sample of naphtha.

..... [1]

**(b)** Compound **V** is found in naphtha. It has a molecular formula $C_{10}H_{22}$.

When **V** is heated at high pressure in the absence of air, an equal number of moles of ethene, propene and **W** are made. **W** is a compound made of straight chain, saturated molecules.

**(i)** Name the process that describes this reaction.

..... [1]

**(ii)** Deduce the structure of **W**. Draw its structure below.

[1]

**(c)** Propene is separated from the mixture and heated in air in the presence of a catalyst. Propene is oxidised to **X**, which contains two functional groups.

**(i)** Effervescence is seen when $Na_2CO_3$(aq) is added to **X**.

Identify the functional group present in **X** which is responsible for this observation.

..... [1]

**(ii)** Identify a reagent which could be used to show that **X** contains a C=C. Include relevant observations.

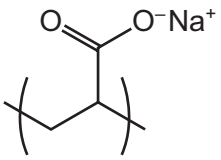
.....

..... [2]

**(d)** **X** reacts with another reagent to form **Y**.

Molecules of **Y** react together to form addition polymer **Z**. The diagram shows the repeat unit of polymer **Z**.

repeat unit of polymer **Z**




Draw the structural formula of monomer **Y**.

[1]

**(e)** Polymer **Z** is useful because it absorbs large amounts of water. However, there are problems associated with the disposal of products containing polymer **Z**.

Combustion is not an appropriate method to dispose of pure **Z** because the process releases harmful gases. Some of these gases contribute to the enhanced greenhouse effect.

**(i)** Identify a gas released during the combustion of **Z** which contributes to the enhanced greenhouse effect.

..... [1]

**(ii)** Identify another gas which could be produced during the combustion of pure **Z**. Describe a consequence, other than the enhanced greenhouse effect, of its release into the atmosphere.

gas .....

consequence .....
[1]

[Total: 10]

**6** Propene, $C_3H_6$, reacts with $H_2O$ in the presence of an acid catalyst to form an alcohol with molecular formula $C_3H_8O$.

**(a)** Name this type of reaction.

..... [1]

**(b)** Name the catalyst used and state the conditions needed for this reaction to occur.

catalyst .....

conditions .....
[2]

**(c)** Complete the table to show the numbers of sigma ($\sigma$) bonds and pi ($\pi$) bonds present in propene, $C_3H_6$, and $C_3H_8O$.

| | $\sigma$ | $\pi$ |
|---|---|---|
| $C_3H_6$ | | |
| $C_3H_8O$ | | |

[2]

**(d)** The reaction of propene, $C_3H_6$, with $H_2O$ occurs in a two-step mechanism. In step 1 $C_3H_6$ reacts with the catalyst, $H^+$, to form a carbocation.

**(i)** Draw structures to identify the more stable and less stable carbocations which can form in step 1. Explain your answer.

| **more** stable carbocation | **less** stable carbocation |
|---|---|
| | |

explanation .....

.....

.....

.....

.....
[3]

**(ii)** Name the major organic product formed from the reaction of propene, $C_3H_6$, with $H_2O$.

..... [1]

**(e)** 2-bromopropane reacts to form propene, hydrogen bromide and water under certain conditions.

**(i)** Name this type of reaction.

..... [1]

**(ii)** Describe the reagents and conditions needed to favour this reaction.

reagents .....

conditions .....
[2]

[Total: 12]

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