Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

7987105346

CHEMISTRY **9701/21**

Paper 2 AS Level Structured Questions **May/June 2018**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
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.

This document consists of **11** printed pages and **1** blank page.

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

1 Sulfuric acid is manufactured by the Contact process.

One stage in this process is the conversion of sulfur dioxide into sulfur trioxide in the presence of a heterogeneous catalyst of vanadium(V) oxide, V_2O_5.

$$2\,O{=}S{=}O(g) + O{=}O(g) \rightleftharpoons 2\,O{=}\overset{\overset{O}{\|}}{S}{=}O(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

(a) (i) State the effect of a catalyst on a reaction.
Explain how a catalyst causes this effect.

.....

.....

.....

..... [2]

(ii) State the meaning of the term *heterogeneous* as applied to catalysts.

.....

.....

..... [1]

(b) Some bond energies are given.

bond	bond energy / kJ mol^{-1}
S=O (in SO_2)	534
O=O	496

Use the data, and the enthalpy change for the conversion of sulfur dioxide into sulfur trioxide, to calculate a value for the S=O bond energy in SO_3.

S=O bond energy in SO_3 = ... kJ mol^{-1} [2]

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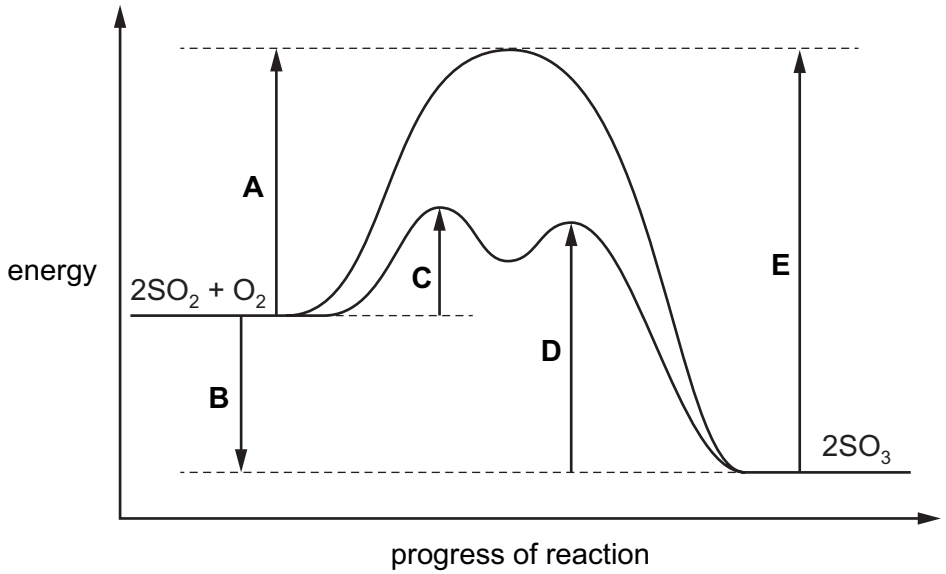
The Contact process is usually carried out at a temperature of about 400 °C and a pressure just above atmospheric pressure. Using a higher or lower temperature and pressure would affect both the rate of production of sulfur trioxide and the yield of sulfur trioxide.

(c) A reaction pathway diagram for both the catalysed and uncatalysed reactions between SO_2 and O_2 is shown.



The letters **A**–**E** represent energy changes.

Complete the table by stating which letter, **A**–**E**, represents the energy change described.

energy change	letter
the energy change for the production of SO_3	
the activation energy for the production of SO_3 in the absence of a catalyst	
the activation energy for the first step in the **decomposition** of SO_3 in the presence of a catalyst	

[3]

The equation for this stage of the Contact Process is shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

(d) (i) State and explain the effect of increasing temperature on the rate of production of SO_3.

.....

.....

.....

..... [3]

(ii) State and explain the effect of increasing temperature on the yield of SO_3.

.....

.....

.....

..... [3]

(e) The SO_3 produced is converted to sulfuric acid in two stages. In the first stage the SO_3 is reacted with concentrated sulfuric acid to produce oleum, $H_2S_2O_7$.
The oleum is then reacted with water to form sulfuric acid.

Suggest an equation for the reaction of oleum, $H_2S_2O_7$, with water to form sulfuric acid.

..... [1]

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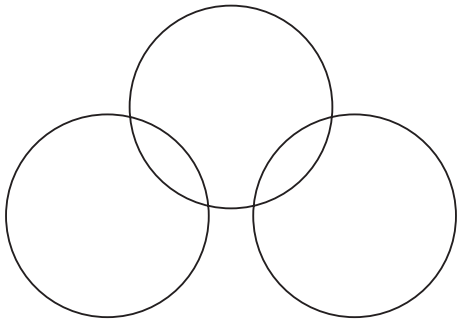
(f) SO_2 reacts with water to form sulfurous acid.
Sulfurous acid is a weak Brønsted-Lowry acid, while sulfuric acid is a strong Brønsted-Lowry acid.

(i) Complete the 'dot-and-cross' diagram to show the bonding in a molecule of SO_2. Show outer electrons only.



[1]

(ii) State the meaning of the term *strong Brønsted-Lowry acid*.

.....

.....

..... [2]

(iii) Write an equation to show the acid-base behaviour of sulfuric acid with water. Include state symbols.

..... [2]

[Total: 20]

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[Turn over

2 Crude oil is a complex mixture of hydrocarbon molecules.

The hydrocarbon molecules in crude oil are separated by fractional distillation. Fractional distillation is used because the different hydrocarbon molecules in crude oil have different boiling points.

(a) Explain why the hydrocarbon molecules in crude oil have different boiling points.

.....

.....

.....

.....

.....

.....

..... [2]

(b) Some of the hydrocarbon molecules obtained from crude oil are processed further by cracking.

Suggest why some hydrocarbon molecules are processed further by cracking.

.....

.....

..... [1]

(c) Cracking one mole of dodecane, $C_{12}H_{26}$, produces two moles of ethene and one mole of another hydrocarbon molecule.

(i) Write the equation for this cracking reaction.

..... [1]

The ethene can be used in the production of poly(ethene).

(ii) Give the full name of the process used to produce poly(ethene) from ethene.

..... [1]

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(iii) Give **two** reasons why poly(ethene) should be reused or recycled rather than just thrown away.

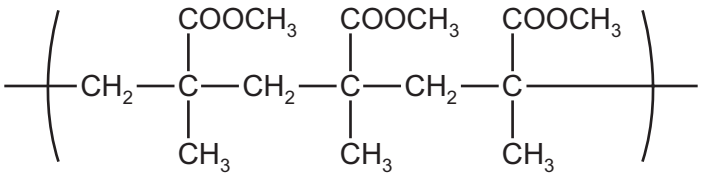
.....

.....

.....

..... [2]

(iv) Part of a polymer chain, produced by the same type of process as poly(ethene), is shown.



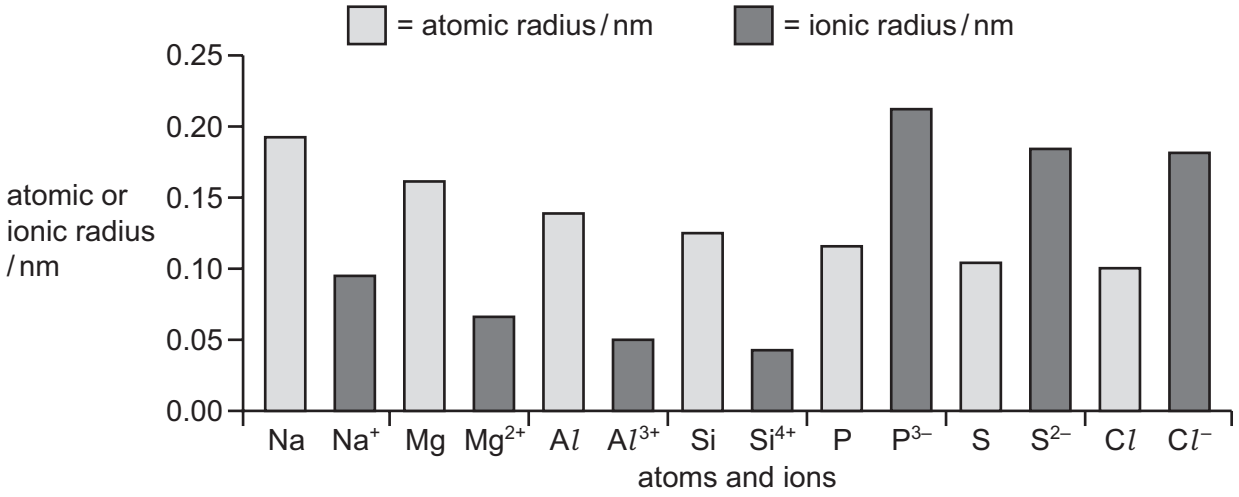
Give the **displayed** formula of the monomer used to produce this polymer.

[2]

[Total: 9]

3 The elements in the third period exhibit periodicity in both their chemical and physical properties.

(a) A graph of the atomic and ionic radii across the third period is shown.



(i) Explain the decrease in atomic radius across the third period.

.....

.....

.....

..... [2]

(ii) Explain why, for sodium to silicon, the ionic radii are less than the atomic radii.

.....

..... [1]

(iii) Explain why, for phosphorus to chlorine, the ionic radii are greater than the atomic radii.

.....

.....

..... [2]

(b) The first ionisation energies of the elements across the third period show a general increase.

Aluminium and sulfur do **not** follow this general trend.

(i) Explain why aluminium has a lower first ionisation energy than magnesium.

.....

.....

..... [2]

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(ii) Explain why sulfur has a lower first ionisation energy than phosphorus.

.....

.....

..... [2]

(c) The elements in the third period, from sodium to silicon, can react with chlorine to form chlorides.

(i) State and explain the pattern of change of oxidation number which occurs to both chlorine and the different Period 3 elements when they react together.

.....

.....

.....

..... [3]

(ii) Give the equations to show the reactions of sodium chloride and silicon(IV) chloride when separately added to water.

sodium chloride .....

silicon(IV) chloride .....
[2]

(iii) Complete the table to describe the structure and bonding in sodium chloride and silicon(IV) chloride.

	structure	bonding
sodium chloride		
silicon(IV) chloride		

[2]

[Total: 16]

4 **X** is $CH_3CH(OH)CH_2CH_3$.

(a) The reaction between **X** and alkaline aqueous iodine produces a yellow precipitate.

(i) Give the name of the compound formed as a yellow precipitate in this reaction.

..... [1]

(ii) Give the name of **X**.

..... [1]

(b) There are three structural isomers of **X** that are alcohols.

Draw the structures of these three isomers of **X**.

[2]

(c) Two reactions of **X** are shown.

$CH_3CH(OH)CH_2CH_3$ (**X**) —reaction **1**→ $CH_3COCH_2CH_3$

X —reaction **2**→ C_4H_8

(i) Identify the type of reaction involved in reaction **1**.

..... [1]

(ii) Identify the reagents for reaction **1**.

..... [1]

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(iii) Reaction **2** can be carried out by passing the vapour of **X** over hot aluminium oxide.

The product of reaction **2**, C_4H_8, is actually a mixture of three isomers.

Give the full names of the three isomers formed by reaction **2**.

1 .....

2 .....

3 .....

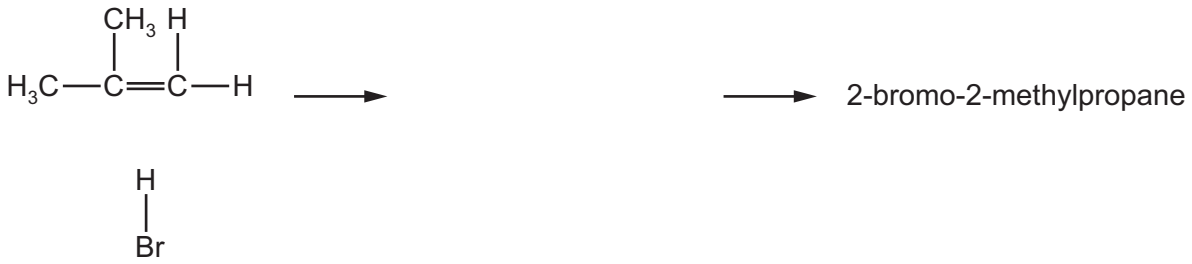
[3]

(d) The reaction of methylpropene, $(CH_3)_2CCH_2$, with hydrogen bromide, HBr, produces a mixture of two halogenoalkanes.

One of the halogenoalkanes, 2-bromo-2-methylpropane, is formed as the major product while 1-bromo-2-methylpropane is formed in small quantities.

(i) Complete the mechanism to show the reaction of methylpropene with HBr to form the **major** product.

Include the structure of the intermediate and all necessary charges, dipoles, lone pairs and curly arrows. The structure of 2-bromo-2-methylpropane is not required.



[4]

(ii) Explain why 2-bromo-2-methylpropane is the major product of this reaction.

.....

.....

.....

..... [2]

[Total: 15]

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