Cambridge Assessment International Education

Cambridge Pre-U

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER			

3382155102

CHEMISTRY **9791/02**

Paper 2 Part A Written **May/June 2023**

2 hours 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 100.
- The number of marks for each question or part question is shown in brackets [ ].

This syllabus is regulated for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate.

This document has **20** pages. Any blank pages are indicated.

DC (PQ/CT) 324830

1 This question is about elements and compounds that are found in milk.

(a) Complete the electronic configuration of a P atom and of a K^+ ion.

P atom:

[Ne] .....

K^+ ion:

$1s^2$ .....

[2]

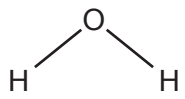
(b) Complete the table for the elements at room temperature and pressure.

element	metal / metalloid / non-metal	gas / liquid / solid	simple / giant structure	formula if simple structure
chlorine	non-metal	gas	simple	Cl_2
sodium				
silicon				
white phosphorus				

[3]

(c) 87.5% of milk is water. Water forms hydrogen bonds.

(i) Complete the diagram to show hydrogen bonding by adding a second water molecule to the diagram.
Include **all** lone pairs and dipoles.



[3]

(ii) State why H_2S does **not** form hydrogen bonds.

.....

..... [1]

(iii) Other than hydrogen bonding, state **two** types of intermolecular forces present in water.

.....

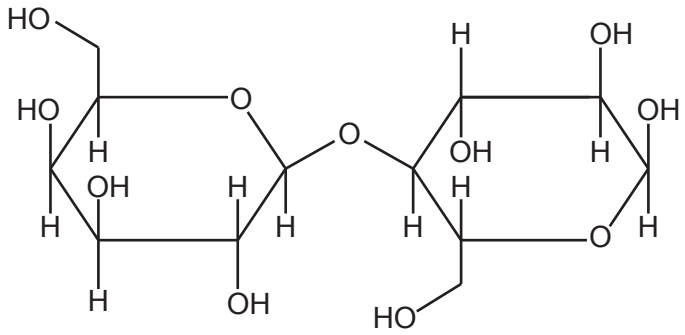
..... [2]

(d) Some of the calcium in milk is in the form of calcium phosphate, $Ca_3(PO_4)_2$.

State the oxidation number of P in calcium phosphate.

..... [1]

(e) Lactose is a sugar present in milk. The structure of lactose is shown. When lactose undergoes hydrolysis two isomers are formed.



(i) State the number of chiral carbon atoms in a molecule of lactose.

..... [1]

(ii) Explain the term *hydrolysis*.

.....

..... [1]

(iii) The molecular formula of each isomer formed by hydrolysis is $C_6H_{12}O_6$.

State the empirical formula of $C_6H_{12}O_6$.

..... [1]

(iv) Calculate the percentage by mass of carbon in $C_6H_{12}O_6$.

percentage by mass = ... [1]

[Turn over

(f) A titration is used to determine the concentration of Ca^{2+} ions in milk.

A 10.00 cm^3 sample of milk is diluted with deionised water and titrated with $EDTA^{4-}$.

The reaction that occurs is shown.

$$\underset{\text{pink/red}}{\text{Ca-IND}} + \text{EDTA}^{4-} \longrightarrow [\text{Ca-EDTA}]^{2-} + \underset{\text{blue}}{\text{IND}^{2-}}$$

IND^{2-} comes from the indicator and $EDTA^{4-}$ comes from the reagent used for the titration.

The end-point of the titration is reached when exactly 10.70 cm^3 of 0.0300 mol dm^{-3} $EDTA^{4-}$ is added.

(i) Calculate the concentration of Ca^{2+} ions, in mg cm^{-3}, present in the sample of milk.
Give your answer to **three** significant figures.
Show your working.

..... mg cm^{-3} [3]

(ii) The minimum requirement of Ca^{2+} ions for a teenager is 800 mg per day.

Use your answer to **(f)(i)** to calculate the minimum volume of milk, in cm^3, a teenager would have to drink per day to meet this requirement. Assume milk is the only form of Ca^{2+} intake.

If you were not able to calculate an answer to **(f)(i)** then assume the answer is 2.37 mg cm^{-3}. This is **not** the correct value.

..... cm^3 [1]

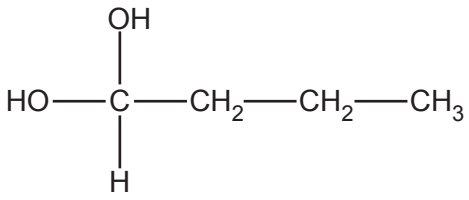
(iii) Suggest a practical reason why the milk is diluted before titration.

.....

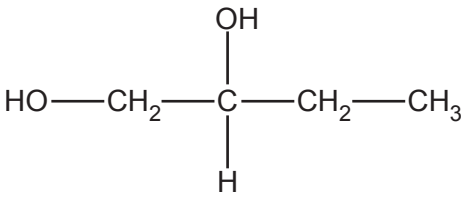
..... [1]

[Total: 21]

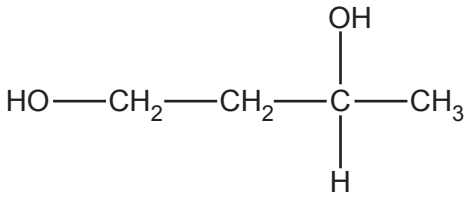
2 Diols have two OH groups. Four diols, **A**, **B**, **C** and **D**, are shown.



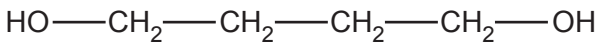
A



B



C



D

(a) Give the systematic name of **C**.

..... [1]

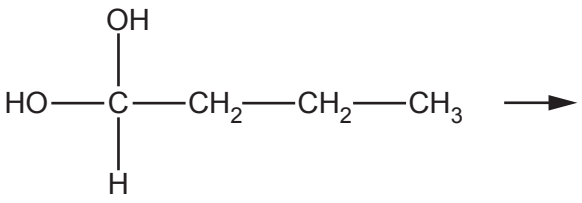
(b) Both **D** and butane have a chain of four carbon atoms.
Explain why **D** is more reactive than butane.

.....

.....

..... [2]

(c) **A** is unstable at room temperature. Complete the equation for the decomposition of **A**.



A

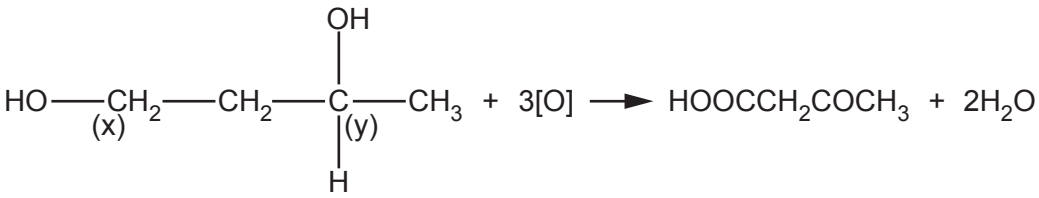
[1]

(d) **B** can be synthesised from 1,2-dibromobutane.
Name a suitable reagent and a suitable solvent for this synthesis.

reagent .....

solvent .....
[2]

(e) The equation for the reaction of **C** with an oxidising agent, [O], is shown.



C

(i) Complete the table to show the functional group level (FGL) of the carbon atoms labelled (x) and (y) before and after this reaction.

carbon	FGL before reaction	FGL after reaction
(x)		
(y)		

[2]

(ii) Identify a suitable oxidising agent for this reaction.

..... [1]

(f) **D** can undergo an elimination reaction to form hydrocarbon **E**.

D

(i) Draw the displayed formula of **E**.

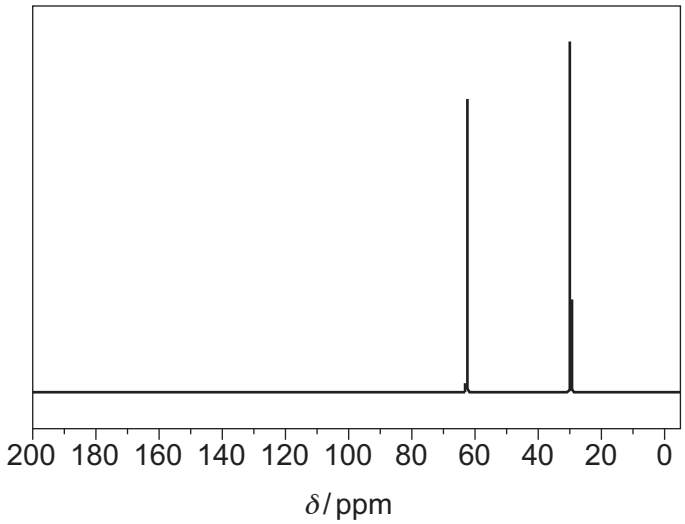
[1]

(ii) State the reagent and conditions for this elimination reaction.

.....

..... [2]

(g) A carbon-13 NMR spectrum is shown.



State which diol, **A**, **B**, **C** or **D**, produces this spectrum. Explain your answer.

diol .....

explanation .....

.....

[1]

(h) Draw the skeletal formulae of **two** further diols which are stable structural isomers of **A**, **B**, **C** and **D**.

[2]

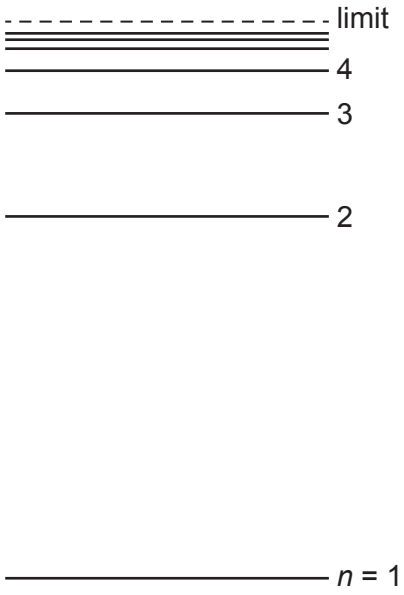
[Total: 15]

3 Elements present in the solar atmosphere absorb specific frequencies of light. This produces a series of black lines within the visible spectrum.

(a) Electronic transitions in hydrogen atoms produce four lines in the visible spectrum. The wavelengths of the lines in order of increasing energy are shown in the table.

line	wavelength / nm
1	656
2	486
3	434
4	410

(i) Complete the diagram with arrows to show the electron transitions which cause lines 1 and 2. Label each arrow.



[3]

(ii) Use the relevant equation in the *Data Booklet* to calculate the energy gap, in J, for line 4. Frequency, f, wavelength, λ, and the speed of light, c, are related by the equation $c = f\lambda$. Show your working.

..... J [2]

(iii) Explain why hydrogen has the simplest spectrum of all atoms. Include in your answer a discussion of shells and subshells.

.....

.....

.....

..... [3]

(iv) Write the equation for the first ionisation energy of hydrogen.

..... [1]

(v) The convergence limit of the series of lines given in the table is equivalent to 5.45×10^{-19} J.
A student used this value to determine the ionisation energy of one mole of hydrogen atoms.
Calculate the ionisation energy, in kJ mol^{-1}, determined from this value.

..... kJ mol^{-1} [1]

(vi) Explain why the ionisation energy in **(a)(v)** is **not** the actual value for the ionisation energy of hydrogen atoms.

.....

..... [1]

(b) Another element in the solar atmosphere is sodium. It produces a line that represents an electronic transition between an s orbital and a p orbital.
Sketch and name the shapes of an s orbital and a p orbital.

s orbital	p orbital
name of shape	name of shape .....

[2]

(c) A line is observed at 358 nm due to the presence of iron in the solar atmosphere. The 3d electrons are in a $3d^7$ configuration for both energy levels of this transition.
Use electron-in-box notation to show the lowest energy arrangement of the 3d electrons in the d^7 configuration.

[1]

(d) The ion $^{40}Ca^{+}$ also exists in the solar atmosphere.
Complete the table to show the number of protons, neutrons and electrons in a $^{40}Ca^{+}$ ion.

	number of protons	number of neutrons	number of electrons
$^{40}Ca^{+}$			

[1]

[Total: 15]

4 This question is about sulfuric acid.

The manufacture of sulfuric acid consists of three steps:

step 1 production of sulfur dioxide
step 2 oxidation of sulfur dioxide to sulfur trioxide
step 3 conversion of sulfur trioxide to sulfuric acid

(a) Some of the sulfur dioxide produced in step 1 is a by-product of burning fossil fuels.

Describe how sulfur dioxide is removed from fossil fuel emissions and suggest how it is then released for use.

.....

.....

..... [2]

(b) In step 2, a mixture of sulfur dioxide, oxygen and sulfur trioxide forms a dynamic equilibrium.

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$$

(i) Explain the term *dynamic equilibrium*.

.....

..... [2]

(ii) The standard enthalpy changes of formation of SO_2 and SO_3 are given in the table.

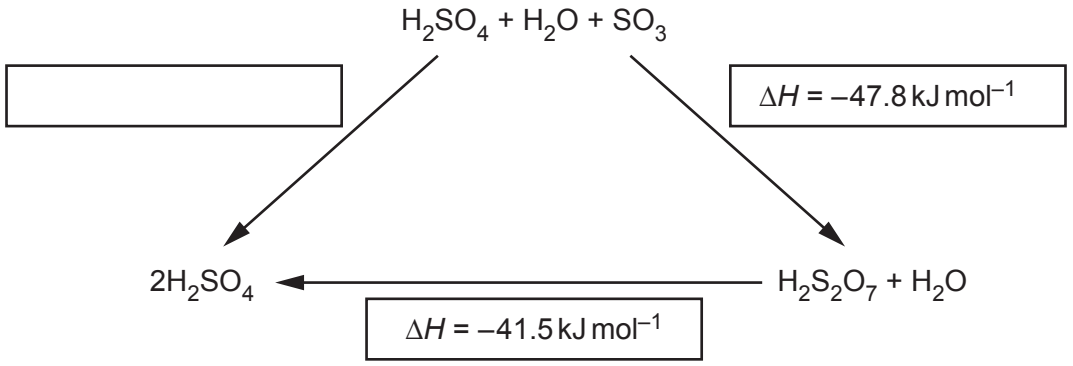
	$\Delta_f H^\ominus$ / kJ mol^{-1}
SO_2	–296.8
SO_3	–395.2

Calculate the standard enthalpy change for the reaction in step 2.

..... kJ mol^{-1} [1]

(c) In step 3, SO_3 is added to concentrated sulfuric acid to form oleum, $H_2S_2O_7$, and then oleum is added to water.

(i) Complete the Hess's law cycle by filling in the box with the corresponding enthalpy change in $kJ\,mol^{-1}$.

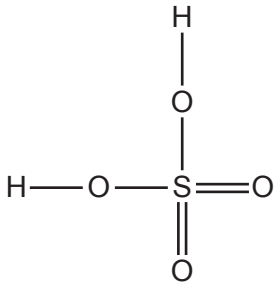


[1]

(ii) Suggest why the two-step route is preferred to direct reaction of SO_3 with water.

..... [1]

(d) The displayed formula of sulfuric acid is shown.



(i) State the number of electrons in the outer shell of the sulfur atom in a molecule of sulfuric acid.

..... [1]

(ii) Suggest a value for the S-O-H bond angle in a molecule of sulfuric acid. State the shape around this oxygen atom.
Explain your answer.

bond angle .....°

shape around O .....

explanation .....

.....

.....

[4]

(e) Sulfuric acid can be described as a strong involatile acid.

(i) Explain the term *involatile*.

..... [1]

(ii) Suggest a reason why sulfuric acid is involatile.

..... [1]

(iii) Explain the term *strong acid*.

.....

..... [2]

(iv) Write an **ionic** equation for dilute sulfuric acid reacting with aqueous sodium carbonate. Include state symbols.

..... [1]

(f) The reactions of halides with concentrated sulfuric acid show a trend towards oxidation.
Describe what would be observed if concentrated sulfuric acid is added to a sample of each of solid KC*l*, KBr and KI.
Write an equation for each halide to show the complete reaction with concentrated sulfuric acid.
For the reaction with KI, give the change in oxidation number of sulfur.

KC*l*

observations .....

.....

equation .....

KBr

observations .....

.....

equation .....

KI

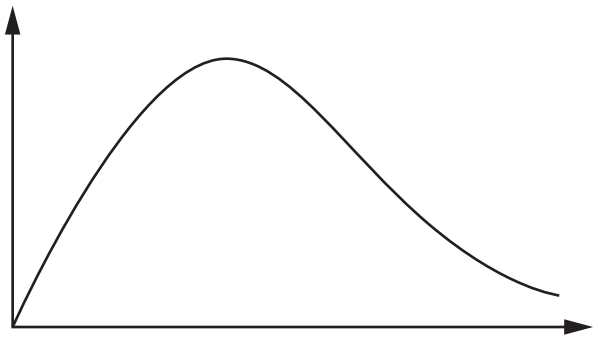
observations .....

.....

equation .....

change in oxidation number of sulfur from ..... to .....
[7]

(g) Sulfuric acid is used as a catalyst in the synthesis of esters. The diagram shows the shape of a typical Maxwell–Boltzmann distribution.



(i) Label the axes on the diagram. [1]

(ii) With reference to the diagram, explain how a catalyst increases the rate of reaction. You may annotate the diagram as part of your answer.

.....

.....

.....

..... [3]

[Total: 28]

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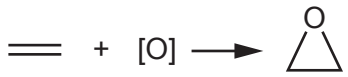
5 This question is about a laboratory method for converting *cis*-hex-3-ene into *trans*-hex-3-ene.

This method involves an oxirane as an intermediate. An oxirane contains a three-membered ring formed from an alkene by the addition of an oxygen atom across the double bond. The equation shows the formation of the simplest oxirane, epoxyethane.



ethene epoxyethane

The laboratory method to convert *cis*-hex-3-ene into *trans*-hex-3-ene takes place in three stages.

In stage 1, ethaneperoxoic acid is prepared in a conical flask.

stage 1 $(CH_3CO)_2O + 2H_2O_2 \longrightarrow 2CH_3COOOH + H_2O$

ethaneperoxoic acid

In stage 2, *cis*-hex-3-ene is added to the conical flask to produce diethyloxirane.

stage 2 $CH_3COOOH + C_6H_{12} \longrightarrow C_6H_{12}O + CH_3COOH$

cis-hex-3-ene diethyloxirane

In stage 3, diethyloxirane is converted to *trans*-hex-3-ene.

stage 3 $C_6H_{12}O + P(C_6H_5)_3 \longrightarrow C_6H_{12} + P(C_6H_5)_3O$

trans-hex-3-ene

(a) (i) Draw the displayed formula of *cis*-hex-3-ene.

[1]

(ii) Draw the displayed formula of diethyloxirane.

[1]

(b) In stage 1, ethaneperoxoic acid is prepared by the reaction of ethanoic anhydride, $(CH_3CO)_2O$, with excess hydrogen peroxide, H_2O_2.

Aqueous hydrogen peroxide is placed in a conical flask and 30.80 cm^3 (0.326 mol) of ethanoic anhydride is added dropwise.

(i) Calculate the volume of $H_2O_2(aq)$ required so that 0.350 mol of H_2O_2 is added to the conical flask.
The $H_2O_2(aq)$ used is 30% hydrogen peroxide by mass.
The density of the $H_2O_2(aq)$ used is 1.11 g cm^{-3}.
Show your working.

volume = ... cm^3 [2]

(ii) State the name of the apparatus used to measure 30.80 cm^3 of ethanoic anhydride.

..... [1]

(iii) An aqueous solution of 30% hydrogen peroxide is corrosive.

Suggest a precaution, other than using a lab coat and goggles, that should be taken when using 30% hydrogen peroxide in a laboratory.

..... [1]

(iv) The reaction in stage 1 gives an 84% yield of ethaneperoxoic acid.
Calculate the amount, in mol, of ethaneperoxoic acid formed.

amount of ethaneperoxoic acid = ... mol [1]

(c) In stage 2, 31.0 cm^3 of *cis*-hex-3-ene is added to the ethaneperoxoic acid in the conical flask from **(b)**. This produces an exothermic reaction.

Suggest **two** ways to prevent the temperature of the mixture in the conical flask rising too high.

1 .....

2 .....
[2]

(d) When the reaction in stage 2 is complete, the reaction mixture contains diethyloxirane, ethanoic acid, organic by-products containing OH groups and water.

Crude diethyloxirane is obtained by solvent extraction using an organic solvent.

(i) Describe how the solvent extraction is carried out.

.....

.....

.....

.....

..... [3]

(ii) Describe a chemical test that would show if all the acid has been removed from the crude diethyloxirane.

..... [1]

(iii) Anhydrous magnesium sulfate is added to the crude diethyloxirane in the organic solvent. State why.

..... [1]

(iv) Name the method used to remove the magnesium sulfate from the crude diethyloxirane.

..... [1]

(v) The organic solvent is evaporated in order to obtain pure diethyloxirane.
State a precaution that should be taken when organic solvents are evaporated.

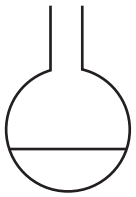
..... [1]

(e) In stage 3, purified diethyloxirane is converted to the final product, *trans*-hex-3-ene by reaction with $P(C_6H_5)_3$.

Some melting points and boiling points are given in the table.

	melting point / °C	boiling point / °C
trans-hex-3-ene	–113	67
diethyloxirane	–	114
$P(C_6H_5)_3$	80	–

(i) Complete the diagram to show how *trans*-hex-3-ene is collected by distillation.



[4]

(ii) The distillate can be tested to see if it is contaminated with ethanoic acid by using IR spectroscopy.

Use the *Data Booklet* to predict what would be observed in the IR spectrum if the product were still contaminated with ethanoic acid.

..... [1]

[Total: 21]

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