Cambridge Pre-U

Cambridge International Examinations
Cambridge Pre-U Certificate

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

2337817921

CHEMISTRY (PRINCIPAL) **9791/02**

Paper 2 Part A Written **May/June 2016**

2 hours 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, if you do not use appropriate units or if you do not give your answer to appropriate significant figures.
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.

For Examiner's Use	
1	
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6	
7	
8	
Total	

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

This document consists of **19** printed pages and **1** blank page.

CAMBRIDGE International Examinations

1 This question is about Period 3 elements and their compounds.

(a) (i) Complete the table to show the number of **unpaired** electrons for the gaseous atoms of silicon, sulfur and argon.

	Si	S	Ar
number of unpaired electrons			

[2]

(ii) Which of these elements, Si, S or Ar, has the highest first ionisation energy?

.....

[1]

(iii) Write the equation to represent the first ionisation energy of silicon.

Include state symbols.

..... [1]

(b) (i) Complete the table to show how some Period 3 chlorides behave when added to water.

Include any relevant observations and suggest the pH of the solution formed in each case.

Period 3 chloride	observations	pH of solution
NaCl		
SiCl_4		
PCl_5		

[4]

(ii) Write an equation for each of the following reactions.

- SiCl_4 and H_2O

.....

- PCl_5 and H_2O

.....

[2]

(c) The Period 3 oxides Na_2O and P_4O_{10} behave differently when added to water.

A spatula measure of each oxide was added to separate test-tubes containing water.

Complete the table to suggest the final pH in each test-tube.

Period 3 oxide	final pH
Na_2O	
P_4O_{10}	

[2]

[Total: 12]

2 **(a)** Dioxygen can exist as the molecule O_2 and as the peroxide ion, O_2^{2-}.

(i) Draw dot-cross diagrams to show the bonding in O_2 and O_2^{2-}.

Show the outer electrons only.

O_2

O_2^{2-}

[2]

(ii) Dioxygen can also exist as the free-radical ion O_2^-.

What is meant by the term *free-radical*?

..... [1]

(b) **(i)** Define the term *standard enthalpy change of atomisation*.

.....

.....

.....

..... [3]

(ii) The bond energy of the O=O double bond is 498 kJ mol^{-1}.

What is the value of the standard enthalpy change of atomisation of oxygen?

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

(c) Oxygen atoms combine to form diatomic molecules rather than eight-membered rings like sulfur. The relevant bond energy values are shown in the table.

bond	bond energy / kJ mol^{-1}
O–O	146
O=O	498

Use the equations and the data provided to explain, with calculations, why the O_2 molecule is the more stable form of oxygen under standard conditions.

$$8O(g) \rightarrow 4O_2(g) \qquad\qquad 8O(g) \rightarrow O_8(g)$$

.....

..... [2]

(d) Hydrogen peroxide can be oxidised by acidified potassium dichromate(VI).

$$Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$$

The half-equation for the reduction of the dichromate(VI) ion is shown below.

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

(i) Use the above equations to construct a half-equation for the oxidation of hydrogen peroxide in this reaction.

[2]

(ii) A sample of hydrogen peroxide completely reacted with 28.50 cm^3 of acidified potassium dichromate(VI) solution.

The concentration of potassium dichromate(VI) was 0.0200 mol dm^{-3}.

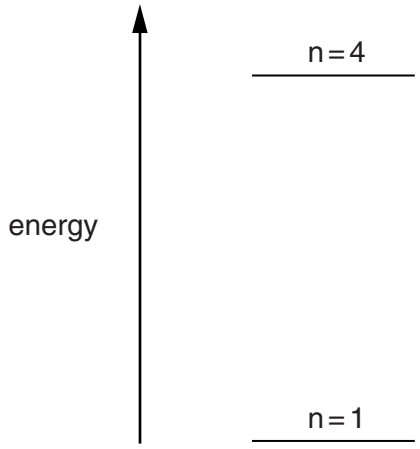
Calculate the volume of oxygen, in cm^3, evolved at room temperature and pressure.

volume of oxygen = ... cm^3 [3]

[Total: 14]

[Turn over

3 (a) (i) Complete the energy level diagram for a hydrogen atom, showing approximately the energy for the n = 2 and n = 3 levels.



[1]

(ii) Add one arrow to the diagram above to represent an electronic transition that is responsible for one of the lines in the atomic emission spectrum of hydrogen. [1]

(iii) State why the subshells within a quantum shell of hydrogen have the same energy.

..... [1]

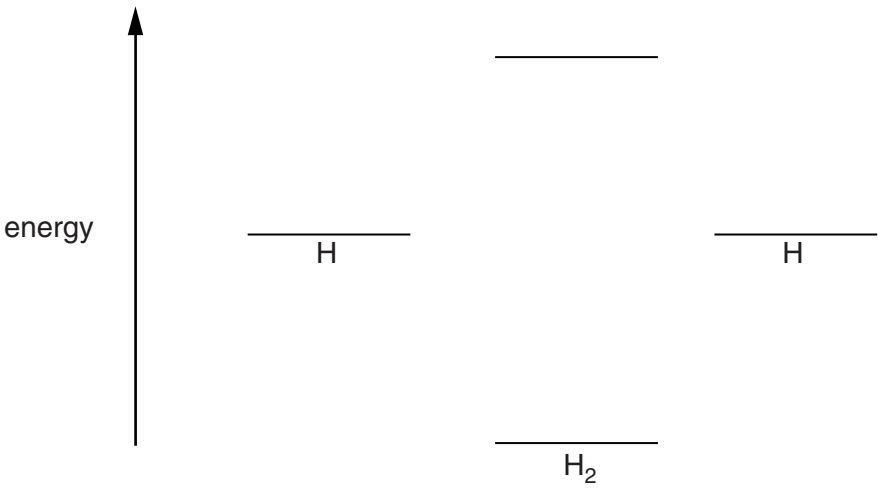
(iv) The first ionisation energy of hydrogen is 1310 kJ mol^{-1}.

Calculate the lowest frequency of electromagnetic radiation, *f*, that would need to be absorbed to remove an electron from a hydrogen atom.

f = ... Hz [2]

(b) (i) Complete the molecular orbital diagram for hydrogen, H_2.

Label **all** the orbitals and include the electrons.



[3]

(ii) The formation of H_2 is favourable but the formation of the molecule He_2 is **not** favourable.

Use the theory of molecular orbitals to explain why He_2 is not formed. Your answer should refer to bond order.

.....

.....

..... [2]

(c) The boiling points of some substances are shown.

substance	boiling point/K
NH_3	240
HF	293
Br_2	332
LiBr	1540
LiCl	1655

Explain the difference between the boiling points of each of the following pairs of substances.

In your answer you should refer to the most important type of force between the particles in each substance and the relative strengths of these forces, and explain why there is a difference in strength of each type of force.

- ammonia and hydrogen fluoride

.....

.....

.....

.....

- lithium bromide and lithium chloride

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- ammonia and bromine

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.....

.....

[6]

[Total: 16]

4 **(a)** Concentrated sulfuric acid, H_2SO_4, is a versatile reagent.

State the role of concentrated sulfuric acid when it is added to each of the following substances. In each case include an equation.

(i) glucose, $C_6H_{12}O_6$, with carbon as a product

role of H_2SO_4 .....

equation .....

[2]

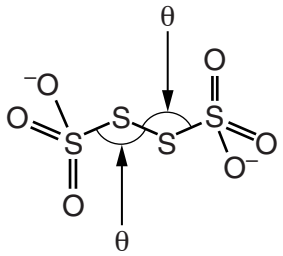
(ii) copper metal, with sulfur dioxide as a product

role of H_2SO_4 .....

equation .....

[2]

(b) The tetrathionate ion, $S_4O_6^{2-}$, contains sulfur atoms that are in two different oxidation states.



(i) Calculate the average oxidation number for sulfur, in $S_4O_6^{2-}$.

average oxidation number for sulfur = ... [1]

(ii) Suggest a value for the bond angle, θ, in $S_4O_6^{2-}$. Explain your answer.

.....

.....

.....

..... [3]

[Total: 8]

5 (a) (i) Define the term *standard enthalpy change of combustion*.

.....

.....

.....

..... [3]

(ii) Write the reaction equation for the standard enthalpy change of combustion of ethanol, C_2H_5OH.

Include state symbols.

..... [2]

(b) (i) When 0.980 g of ethanol was combusted using a spirit burner, the energy released heated 100 cm^3 of water from 21.0 °C to 58.6 °C.

The transfer of the heat evolved in the reaction to the water was only 65% efficient.

Calculate the enthalpy change of combustion of ethanol.

Assume the specific heat capacity of water is 4.18 $J\,g^{-1}\,K^{-1}$. The molar mass of ethanol is 46.0 $g\,mol^{-1}$.

enthalpy change of combustion of ethanol = ... $kJ\,mol^{-1}$ [3]

(ii) An accurate value for the standard enthalpy change of combustion of ethanol is –1370 kJ mol^{-1}.

Suggest why the value calculated in **(b)(i)** is less exothermic than the accurate value, despite having taken into account the efficiency of the heat transfer to the water.

.....

..... [1]

(iii) A student repeated this experiment to find the enthalpy change of combustion of ethanol. In the calculation the student incorrectly used a smaller value for the molar mass of ethanol.

State and explain what effect this error would have on the calculated enthalpy change of combustion of ethanol.

.....

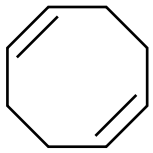
.....

..... [1]

[Total: 10]

6 (a) (i) There are **three** possible isomers of cyclooctadiene that contain only an eight-membered ring. One of these, **P**, is given.

Give the structures of the other two isomers.

	P	Q	R
structure			

[2]

(ii) What is meant by the term *empirical formula*?

.....

..... [1]

(iii) What is the empirical formula of cyclooctadiene?

..... [1]

(iv) Predict the number of peaks that would be seen in the carbon-13 NMR spectrum of the isomer **P**.

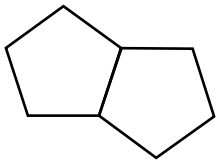
..... [1]

(v) Give the expected chemical shifts of the peaks you predicted for the carbon-13 NMR spectrum of **P**.

[2]

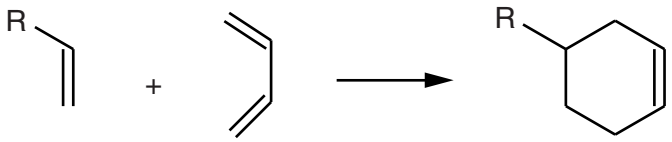
(vi) The bicyclic hydrocarbon C_8H_{10} has a carbon-13 NMR spectrum containing four peaks.

Complete the structure of this hydrocarbon.



[1]

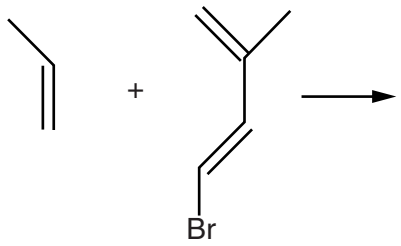
(b) The Diels-Alder reaction is used to form a cyclohexene ring from an alkene and a diene.



(i) What type of reaction is a Diels-Alder reaction?

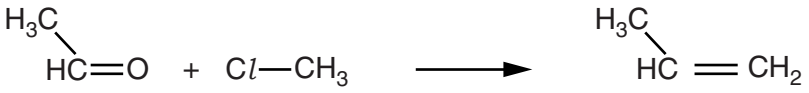
..... [1]

(ii) Suggest the two possible **structural** isomers formed if the following compounds are used.

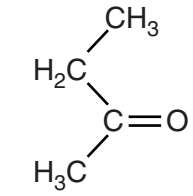


[2]

(c) The Wittig reaction is used to synthesise new carbon-carbon double bonds by the reaction of a halogenoalkane with a carbonyl compound under certain conditions, as shown by the scheme.



Give the names and draw the structures of the **two** geometric isomers formed from the reaction of the following compounds.



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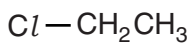

name

name

[3]

(d) A mass spectrometer is used in the identification of organic compounds.

(i) After vaporisation of the sample, **two** physical processes take place before the ions are separated by time-of-flight detection.

Name the **two** physical processes.

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

(ii) Outline how mass spectrometers separate ions by time-of-flight detection.

.....

.....

.....

..... [3]

[Total: 19]

Question 7 begins on page 16.

7 A sample of river water was treated with excess ethanedioic acid, HOOCCOOH, to precipitate all the Ca^{2+} ions as calcium ethanedioate, CaC_2O_4. The precipitate was separated from the mixture using standard laboratory equipment.

(a) (i) Describe how you would obtain a pure sample of CaC_2O_4 from the mixture.

.....

.....

..... [2]

(ii) The pure sample obtained was heated strongly in a crucible. It decomposed to leave calcium oxide, CaO.

The pure sample of CaC_2O_4 was found to have a mass of 0.565 g.

Calculate the maximum mass of CaO that could be obtained by the decomposition of this sample.

maximum mass of CaO = ...g [2]

(iii) What would need to be done to confirm that this decomposition is complete?

.....

..... [1]

(b) A 'healthy' river has a dissolved oxygen concentration of at least 6×10^{-3} g dm^{-3}. A sample of river water was analysed to find the amount of dissolved oxygen present.

step 1 A 250 cm^3 sample of river water was treated with an excess of manganese(II) hydroxide, $Mn(OH)_2$. All the dissolved oxygen reacted with the $Mn(OH)_2$.

$$2Mn(OH)_2(s) + ½O_2(aq) + H_2O(l) \longrightarrow 2Mn(OH)_3(s)$$

step 2 The precipitate of manganese(III) hydroxide, $Mn(OH)_3$, was dissolved in acid and treated with excess iodide ions, I^-, to liberate iodine, $I_2(aq)$.

$$2Mn(OH)_3(s) + 2I^-(aq) + 6H^+(aq) \longrightarrow 2Mn^{2+}(aq) + I_2(aq) + 6H_2O(l)$$

step 3 The solution was titrated with a standard solution of sodium thiosulfate.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \longrightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

The titration required 25.60 cm^3 of 0.00500 mol dm^{-3} sodium thiosulfate.

(i) Calculate the concentration of dissolved oxygen in $g\,dm^{-3}$ and comment on the 'health' of the river water.

Give your answer to **three** significant figures. Show your working.

concentration of dissolved oxygen = ...$g\,dm^{-3}$

comment .....

.....

[5]

(ii) In **step 3** an indicator was used.

- Name the indicator used in **step 3**.

.....

- What colour change would you observe at the end-point in this titration?

..... to .....

- At what stage in the titration would you add the indicator?

.....

[3]

[Total: 13]

8 You are to describe how you would carry out an experiment to determine the enthalpy change for the reaction between zinc and copper(II) sulfate.

$$Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$$

(a) You are provided with $1.0\,mol\,dm^{-3}$ aqueous copper(II) sulfate solution, zinc powder and standard laboratory equipment.

- Give a step-by-step description of how you would carry out the experiment.
- Suggest suitable quantities to be used in this experiment. Include any calculations relevant to these quantities.

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..... [6]

(b) Explain how you would use your results to calculate the enthalpy change for this reaction.

.....

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.....

..... [2]

[Total: 8]

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