UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
Cambridge International Level 3 Pre-U Certificate
Principal Subject

CANDIDATE NAME

CENTRE NUMBER | CANDIDATE NUMBER

4594764516

CHEMISTRY **9791/02**

Paper 2 Part A Written **May/June 2012**

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 in the spaces provided.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
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.

For Examiner's Use	
1	
2	
3	
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7	
Total	

This document consists of **18** printed pages and **2** blank pages.

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UNIVERSITY *of* CAMBRIDGE International Examinations

[Turn over

For Examiner's Use

1 Magnesium powder is used to generate heat for battlefield soldiers wanting a hot drink.

9.0 g of magnesium powder is added to 30.0 g, an excess, of water.

$$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$$

(a) Calculate the amount, in mol, of magnesium.

.... mol [1]

(b) Calculate the mass of water that is in excess.

.... g [2]

(c) Calculate the volume of hydrogen gas, in dm^3, produced at room temperature and pressure.

.... dm^3 [1]

(d) Use the standard enthalpy change of formation data in Table 1.1 to calculate the standard enthalpy change of reaction for magnesium reacting with water.

Table 1.1

substance	$\Delta_f H^{\ominus}$ / kJ mol^{-1}
H_2O	−285.8
$Mg(OH)_2$	−924.5

.... kJ mol^{-1} [2]

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(e) Calculate the heat energy, in kJ, released when 9.0 g of magnesium powder is added to 30.0 g of water.

.... kJ [1]

(f) When the magnesium powder and water are mixed, the temperature of the drink being heated can rise to 60 °C in about 10 minutes.
Calculate how much energy, in kJ, is required to heat 150 g of the drink from 15 °C to 60 °C. Assume that the specific heat capacity of the drink is 4.2 $J g^{-1} K^{-1}$.

.... kJ [1]

(g) How would using 9.0 g of magnesium **granules** affect the amount of energy released and the temperature reached of the drink? Explain your answer.

....

....

.... [2]

(h) Exothermic reactions that do **not** produce hydrogen gas are being explored.

(i) One example is mixing calcium oxide with water. Write an equation for this reaction and give the approximate pH of the resulting solution.

……………………………………………………………………… pH........................ [2]

(ii) Another example is the reaction of phosphorus(V) oxide with water. Write an equation for this reaction and give the approximate pH of the resulting solution.

……………………………………………………………………… pH........................ [2]

(iii) Calcium oxide reacts with phosphorus(V) oxide to make calcium phosphate. Write an equation for this reaction.

....[1]

[Total: 15]

For Examiner's Use

2 **(a)** **(i)** What is meant by the term *bond energy*?

....

....

.... [3]

(ii) Use the bond energy data in Table 2.1 to find the enthalpy change of reaction for the reaction between ethane and chlorine shown below.

$$C_2H_6(g) + 2Cl_2(g) \longrightarrow C_2H_4Cl_2(g) + 2HCl(g)$$

Table 2.1

bond	average bond energy / kJ mol^{-1}
C−C	347
C−H	413
Cl−Cl	243
C−Cl	346
H−Cl	432

[3]

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(b) At low temperatures and pressures the alkali metals can exist as gaseous diatomic molecules. Recent research has investigated the mixing of gaseous diatomic molecules of different alkali metals (reported in *Science* 2010).

Spectroscopic techniques can be used to measure the bond energies of diatomic molecules. When measured in this way the values of bond energies are given in wavenumbers, which has the unit cm^{-1}.

Some values are shown in Table 2.2.

Table 2.2

diatomic molecule	bond energy / cm^{-1}
K_2	4405
Rb_2	3966
KRb	4180

(i) Calculate the enthalpy change, in cm^{-1}, for the reaction between K_2 and Rb_2.

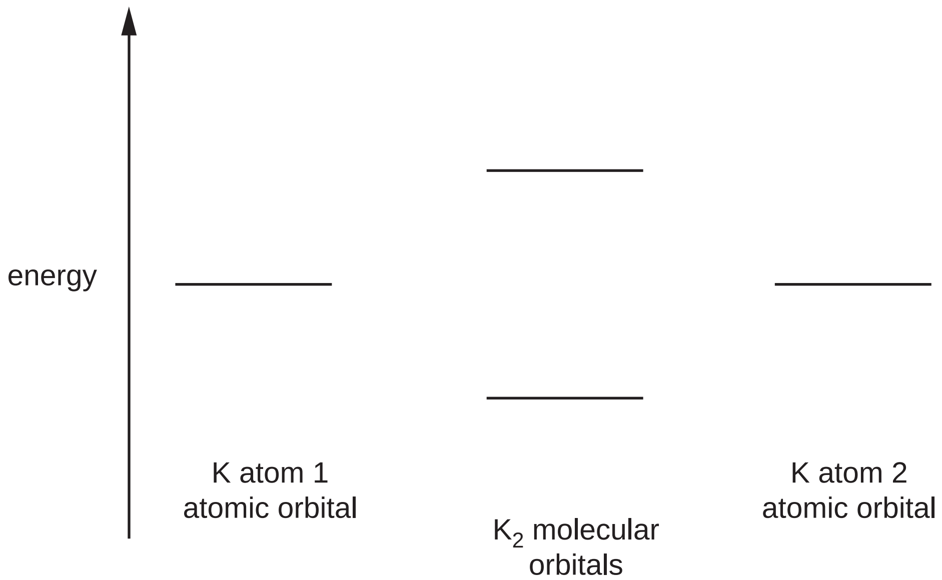
$$K_2(g) + Rb_2(g) \longrightarrow 2KRb(g)$$

.... cm^{-1} [1]

(ii) Complete the electron configuration of a potassium atom.

$1s^2$ .... [1]

(iii) If only the outer shell electrons are considered, the molecular orbital diagram for an alkali metal diatomic molecule is much like that for hydrogen, H_2. Label all the orbitals in the molecular orbital diagram for K_2 and include the electrons.



[3]

(iv) Explain why potassium has a greater first ionisation energy than rubidium.

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....

....

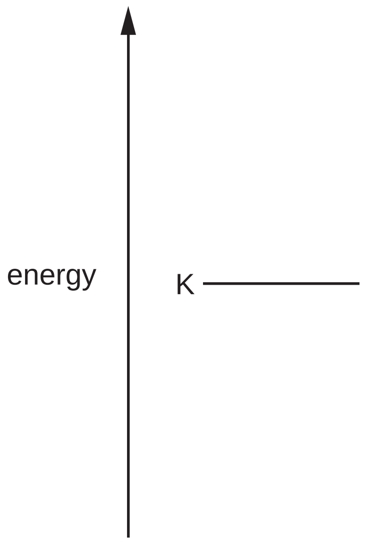
....

....

....

....[3]

(v) Complete the molecular orbital diagram for KRb, showing relevant atomic and molecular orbitals. Only include outer shell orbitals. Label all the orbitals in your diagram.



[2]

(vi) Wavenumbers, $\bar{v}$, are converted into energy, E, using the equation

$$E = hc\bar{v}$$

where h is Planck's constant and c is the speed of light.

Using your answer to **(b)(i)**, work out the enthalpy change in $kJ\,mol^{-1}$ for the reaction between K_2 and Rb_2.

.... $kJ\,mol^{-1}$ [2]

[Total: 18]

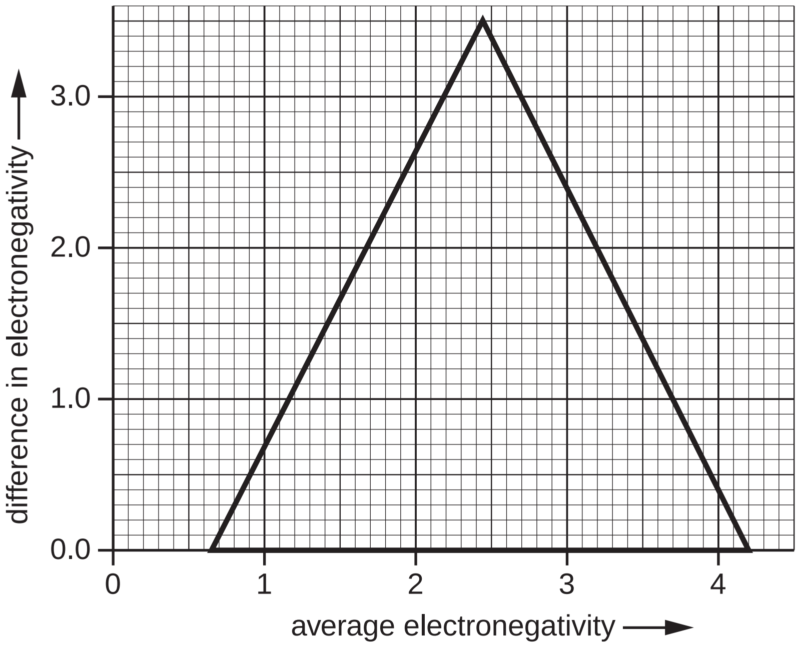
For Examiner's Use

3 **(a)** Binary compounds such as cadmium sulfide, CdS, can be used to improve the efficiency of catalysts. The electronegativity values of cadmium and sulfur are shown in Table 3.1.

Table 3.1

element	electronegativity
cadmium	1.52
sulfur	2.59

(i) Plot the position of CdS on the van Arkel triangle below.



[1]

(ii) Circle the option that best describes the bonding in CdS.

ionic **covalent** **metallic**

intermediate ionic-metallic **intermediate covalent-ionic**

intermediate covalent-metallic **intermediate covalent-ionic-metallic**

[1]

For Examiner's Use

(b) Some bacteria can oxidise methane to carbon dioxide in the absence of oxygen. It has recently been reported that the mechanism involves a reaction between methane and nitrite ions in acidic conditions (reported in *Nature*, 2010).

The half-equation for the oxidation of methane is:

$$CH_4 + 2H_2O \rightarrow CO_2 + 8H^+ + 8e^-$$

(i) Write a half-equation for the reduction of NO_2^- in acidic conditions to give N_2.

.... [2]

(ii) By combining the half-equations, or otherwise, balance the overall equation shown below.

......CH_4 + ...NO_2^- + ...H^+ $\rightarrow$ ......CO_2 + ...N_2 + ...H_2O [1]

(iii) The oxidation of methane by nitrite ions is thermodynamically favourable but will not occur under standard laboratory conditions. Suggest briefly the role of bacteria in this reaction.

....

.... [1]

(c) Molybdenum can form many complex oxy-ions. It has been reported that a complex molybdenum oxyanion can self-assemble to a large doughnut-shaped structure with a 3.6 nm diameter (reported in *Science*, 2010). The oxyanion unit has the formula $[Mo_{36}O_{112}(H_2O)_{16}]^{8-}$.

(i) Calculate the oxidation state of molybdenum in this oxyanion unit.

[1]

(ii) Give the empirical formula of the oxyanion unit.

.... [1]

[Total: 8]

4 The Strecker synthesis is a route to preparing amino acids. Glycine, 2-aminoethanoic acid, can be prepared from methanal in this way. This is shown in the four-reaction scheme below.

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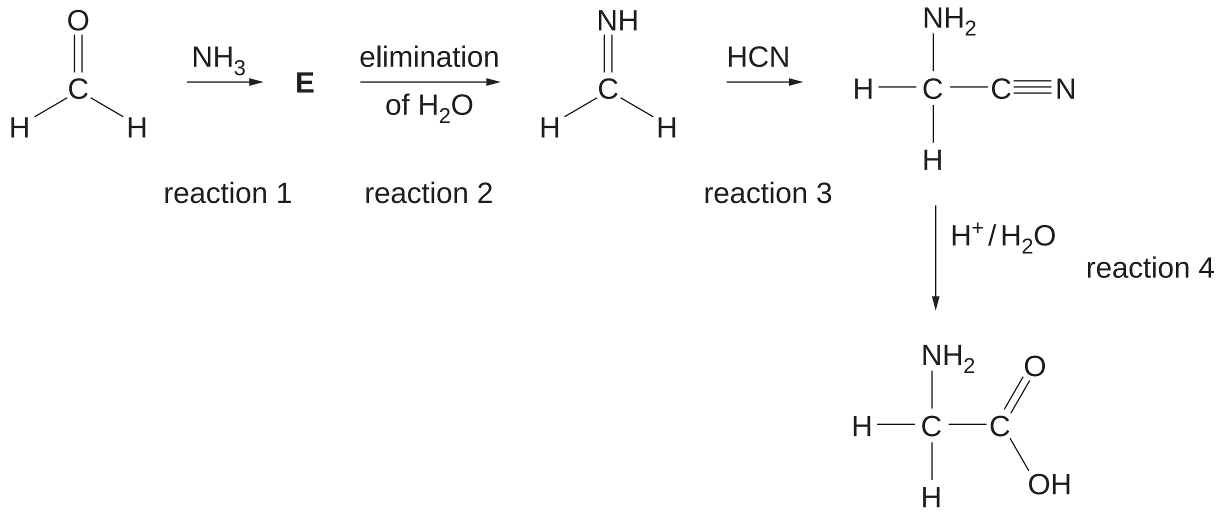


(a) Circle the atom in methanal that is attacked by the ammonia molecule. [1]

(b) What kind of reagent is ammonia, in the context of this synthesis?

.... [1]

(c) Suggest a structure for compound **E**.

[1]

(d) What type of reaction is reaction 3?

.... [1]

(e) The product of reaction 2 is an imine. Name a compound, which does not contain nitrogen, that undergoes a similar reaction with HCN.

.... [1]

(f) What type of reaction is reaction 4?

.... [1]

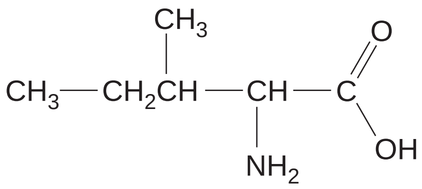
(g) State the functional group level of the carbon atom in methanal and the functional group level of this carbon atom in the product of reaction 2 and the product of reaction 3.

methanal ....

product of reaction 2 ....

product of reaction 3 .... [3]

(h) The amino acid shown is isoleucine, 2-amino-3-methylpentanoic acid.



Molecule **Z** can be used as the starting material to prepare this amino acid using a Strecker synthesis.

(i) Draw the structure of **Z**.

[1]

(ii) Name molecule **Z**.

.... [1]

(i) Alanine, 2-aminopropanoic acid, can be made in a similar way, but the synthesis produces a mixture of two optical isomers.

Draw the optical isomers of alanine.

[2]

[Total: 13]

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5 **(a)** Chemists have recently established that four molecules of water are required for the dissociation of a single molecule of HC*l* (reported in *Science*, 2009).

Given that 1.00 dm^3 of water contains 55.6 mol of H_2O, calculate the maximum mass of hydrogen chloride, HC*l*, that should therefore dissociate in 1.00 dm^3 of water.

.... g [1]

(b) Commercial concentrated hydrochloric acid, HC*l*(aq), fumes strongly on exposure to moist air and so is also known as 'fuming hydrochloric acid'.

1.00 cm^3 of fuming hydrochloric acid was transferred with a graduated pipette to a 100 cm^3 volumetric flask. The volume was made up to 100 cm^3 with deionised water. The solution was labelled **F**. 10.0 cm^3 of solution **F** was neutralised by 24.75 cm^3 of 0.0500 mol dm^{-3} of aqueous sodium hydroxide.

Calculate the concentration of HC*l* in the fuming hydrochloric acid in mol dm^{-3}. Give your final answer to **three** significant figures.

.... mol dm^{-3} [4]

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(c) Historically, hydrochloric acid, $HCl(aq)$, was produced by mixing concentrated sulfuric acid with sodium chloride and dissolving the gas produced in water.

(i) Write an equation for the production of gaseous hydrogen chloride by this method.

.... [1]

Hydrobromic acid, $HBr(aq)$, cannot be prepared in the same way as hydrochloric acid because a redox reaction occurs between hydrogen bromide and sulfuric acid.

(ii) Write a balanced equation for the reaction of hydrogen bromide with sulfuric acid.

.... [1]

(iii) Identify the oxidising agent in the reaction. Justify your answer using oxidation numbers.

....

....

.... [2]

(d) **(i)** State and explain the trend in bond strength for the gases hydrogen chloride, hydrogen bromide and hydrogen iodide, in that order.

....

.... [1]

(ii) State and explain the trend in acidic strength of hydrochloric acid, hydrobromic acid and hydroiodic acid.

....

....

.... [1]

(iii) Describe and explain the variation in boiling point of the gases hydrogen fluoride, hydrogen chloride, hydrogen bromide and hydrogen iodide.

....

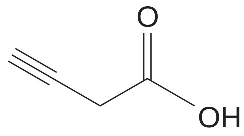
....

....

.... [2]

[Total: 13]

6 The molecule shown is but-3-ynoic acid.



(a) Give the molecular formula for but-3-ynoic acid.

molecular formula .... [1]

(b) Draw the structure and name an isomer of but-3-ynoic acid that contains the same functional groups.

structure

name... [2]

(c) Work out the percentage composition (by mass) of the constituent elements in but-3-ynoic acid.

C .... % H .... % O .... % [2]

(d) Give the m/z value of the molecular ion peak in the mass spectrum of but-3-ynoic acid.

.... [1]

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(e) **(i)** But-3-ynoic acid contains a carboxylic acid group with double and single bonds. Write down a value in cm^{-1} that falls in the wavenumber range of each of these types of bonds in an infrared spectrum.

double bonds .... cm^{-1}

single bonds (not involving hydrogen) .... cm^{-1}

single bonds to hydrogen .... cm^{-1}

[2]

(ii) The carboxylic acid O–H stretch has a characteristic appearance in an infrared spectrum. Describe its general appearance. There is no need to give wavenumber values.

....

.... [1]

(f) Scientists recently isolated a novel, highly toxic and unstable molecule, **T**, from the poisonous Asian mushroom *Russula subnigricans* (reported in *Nature Chemical Biology*, 2009).

T is an isomer of but-3-ynoic acid. Its infrared spectrum indicates that **T** also contains a carboxylic acid group. Its carbon-13 nmr spectrum, however, only contains 3 signals.

Suggest a structure for **T**.

[1]

[Total: 10]

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QUESTION 7 BEGINS ON PAGE 16

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7 **(a)** The following six organic liquids are in unlabelled bottles.

1-chloropropane	propan-1-ol	propanal
1-iodopropane	propan-2-ol	hexane

Propose a series of **wet chemical** tests, using a flowchart or otherwise, whose results could be used to identify each of the organic liquids.

Your answer should include the tests, observations and deductions. You have enough of the samples for multiple tests, and access to reagents commonly available in school laboratories.

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[15]

QUESTION 7 CONTINUES ON PAGE 18

[Turn over

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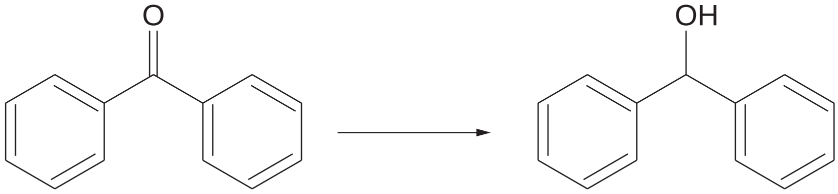
(b) Benzophenone, **X**, is a white crystalline solid with a melting point of 48 °C. It can be reduced to form diphenylmethanol, **Y**, a white solid with a melting point of 69 °C.



benzophenone, **X** diphenylmethanol, **Y**

Outline a laboratory scale method to prepare a **pure** sample of **Y** from a sample of **X**.

You will need to specify:

- a suitable reducing agent
- the experimental techniques involved
- solvents used at each stage
- how the raw product is separated
- how the raw product is purified
- how the purity of the product is checked

Specific quantities are not required. Diagrams are not necessary.

The following solvents are available: water, ethanol, ether (ethoxyethane) and hexane.

The solubility of **X** and **Y** in the solvents is shown in Table 7.1.

Table 7.1

solvent	solubility of **X**	solubility of **Y**
water	insoluble	slightly soluble
ethanol	very soluble	very soluble
ether (ethoxyethane)	very soluble	very soluble
hexane	slightly soluble when cold appreciably soluble when hot	slightly soluble when cold appreciably soluble when hot

You may wish to express your answer as a series of bullet points.

....

....

....

....

....

....

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[8]

[Total: 23]

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