INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME			
CLASS		INDEX NUMBER	

CHEMISTRY 8872/02

18 August 2016

Paper 2 **2 hours**

Candidates answer Section A on the Question Paper.

Additional Materials: Data Booklet
Writing Papers

READ THESE INSTRUCTIONS FIRST

Write your index number, name and civics group.
Write in dark blue or black pen.
You may use pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A: Structured Questions (40m)
Answer **all** questions in the spaces provided.

Section B: Free Response Questions (40m)
Answer **two** questions on writing papers provided.

A *Data Booklet* is provided.

You are advised to show all working in calculations.
You are reminded of the need for good English and clear presentation in your answers.
You are reminded of the need for good handwriting.
Your final answers should be in 3 significant figures.

You may use a calculator.

The number of marks is given in brackets [ ] at the end of each question or part question.

At the end of the examination, fasten all your work securely together.

For Examiner's Use	
Section A	
1	/8
2	/12
3	/10
4	/10
Section B	
	/20
	/20
Significant figures	
Handwriting	
Total	/80

This document consists of **15** printed pages and **1** blank page.

Section A

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

1 Magnesium exists as three principal isotopes, ^{24}Mg, ^{25}Mg and ^{26}Mg.

Isotope	Relative isotopic mass	Natural abundance (%)
^{24}Mg	23.99	78.99
^{25}Mg	24.99	10.00
^{26}Mg	25.98	11.01

(a) Use the above data to calculate the relative atomic mass of magnesium to **two** decimal places.

[1]

(b) Magnesium and phosphorus are both in period 3. Describe and explain the difference in the size of their atomic radii.

……

……

…….…….... [2]

(c) Write equations for the reactions of the following oxides with aqueous hydrochloric acid and with aqueous sodium hydroxide.

(i) with aqueous hydrochloric acid

aluminium oxide ……..

magnesium oxide ……..
[2]

(ii) with aqueous sodium hydroxide

aluminium oxide ……..

phosphorus(V) oxide ……
[2]

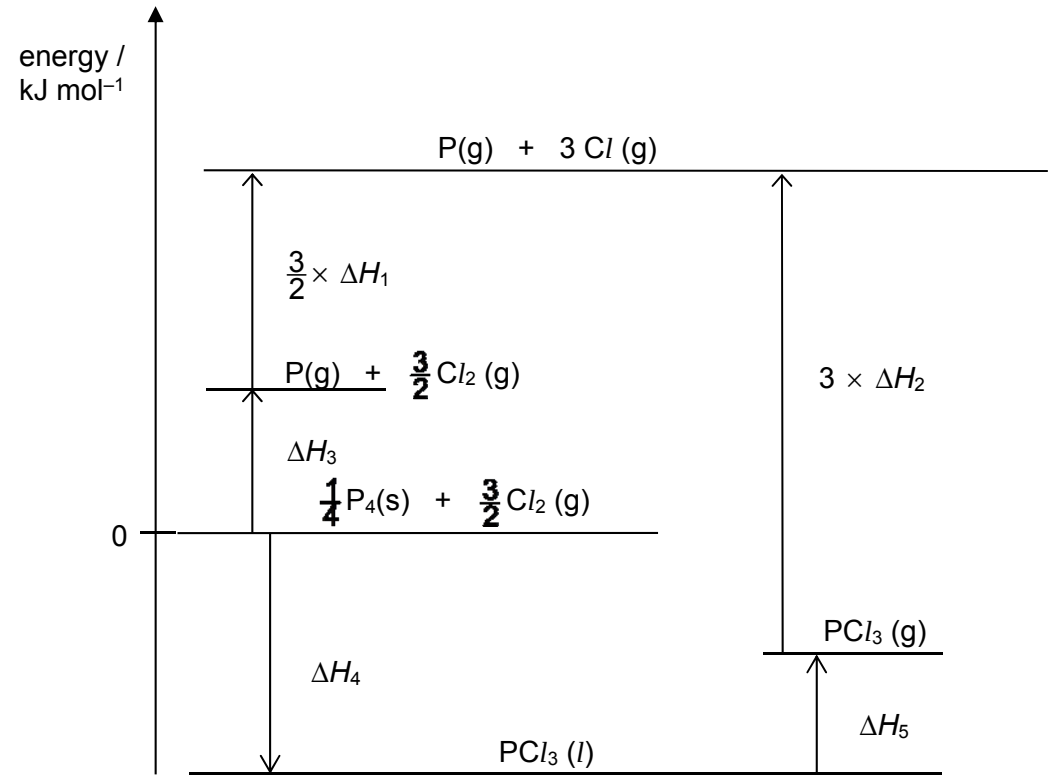
(d) Explain why aluminum oxide exhibits character of both magnesium oxide and phosphorus (V) oxide.

……

…….…….... [1]

[Total: 8]

2 **(a)** Liquid phosphorous trichloride can be prepared in the laboratory by the reaction of chlorine with red phosphorus. An energy level diagram which starts from $P_4(s)$ and $Cl_2(g)$ is shown below.



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

……

……

…… [1]

(ii) State the enthalpy changes that are represented by ΔH_1, ΔH_2 and ΔH_4.

ΔH_1 ……

ΔH_2 ……

ΔH_4 ……

[2]

(iii) Hence, use the information given below and relevant data from the *Data Booklet* to calculate the bond energy of P–C*l* bond.

ΔH_3	+314.6 kJ mol^{-1}
ΔH_4	–319.7 kJ mol^{-1}
ΔH_5	+31.0 kJ mol^{-1}

[2]

(b) The reaction between **A** and **B** is monitored by finding the time taken for **A**, a coloured reactant to decolourise. Water is added to the reaction mixture to keep the volume of the reaction mixture for experiment 1, 2 and 3 constant at 60 cm^3.

A + **B** ⟶ **D**

The following results are obtained:

experiment	volume of **A** added/cm^3	volume of **B** added/cm^3	volume of H_2O added/cm^3	relative rate of reaction
1	10	20	30	1
2	15	40	5	6
3	20	20	20	2

(i) Explain why is there a need to keep the total volume of the reaction mixture constant.

……

……

…….. [1]

(ii) Deduce, showing your working, the orders of reaction with respect to **A** and **B**.

……

……

……

……

……

……

…….. [2]

(iii) Hence, state the overall rate equation for this reaction.

…….. [1]

(c) Explain, with an aid of the Maxwell-Boltzmann distribution curve, the effect of increasing temperature on the rate of the reaction.

……

……

……

……

…….. [3]

[Total: 12]

3 Beryllium chloride, $BeCl_2$, is an inorganic solid that dissolves well in polar solvents. At solid state, $BeCl_2$ molecules undergo polymerisation to form a long chain. In vapour phase, $BeCl_2$ exists as a dimer, and at higher temperature, it exists as individual molecules.

(a) **(i)** Draw the dot-and-cross diagram of a molecule of $BeCl_2$. State the shape of the molecule.

shape of molecule ……

[2]

(ii) By considering the lone pairs and valence electrons on the atoms of $BeCl_2$ molecules, suggest the type of bonding formed during the polymerisation process.

……..…….. [1]

(b) Draw the shape of all the valence orbitals of chlorine.

[2]

(c) $Ba(OH)_2$ is a *strong base*.

(i) Define the term *strong base*.

…….....

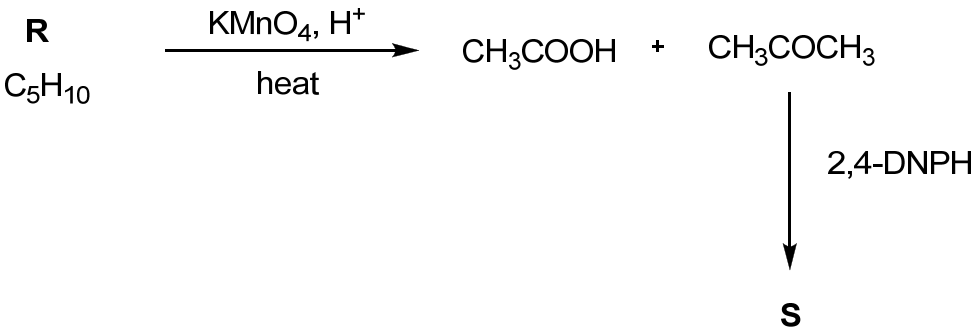
…….....

……..…….. [1]

(ii) Given that $Ba(OH)_2$ is a strong diacidic (diprotic) base, calculate the pH of a 0.01 mol dm^{-3} solution of $Ba(OH)_2$ at 25°C.

[1]

(d) The reaction scheme shows the reactions for alkene **R** and its product.



(i) Suggest the structures for **R** and **S**.

R	S

[2]

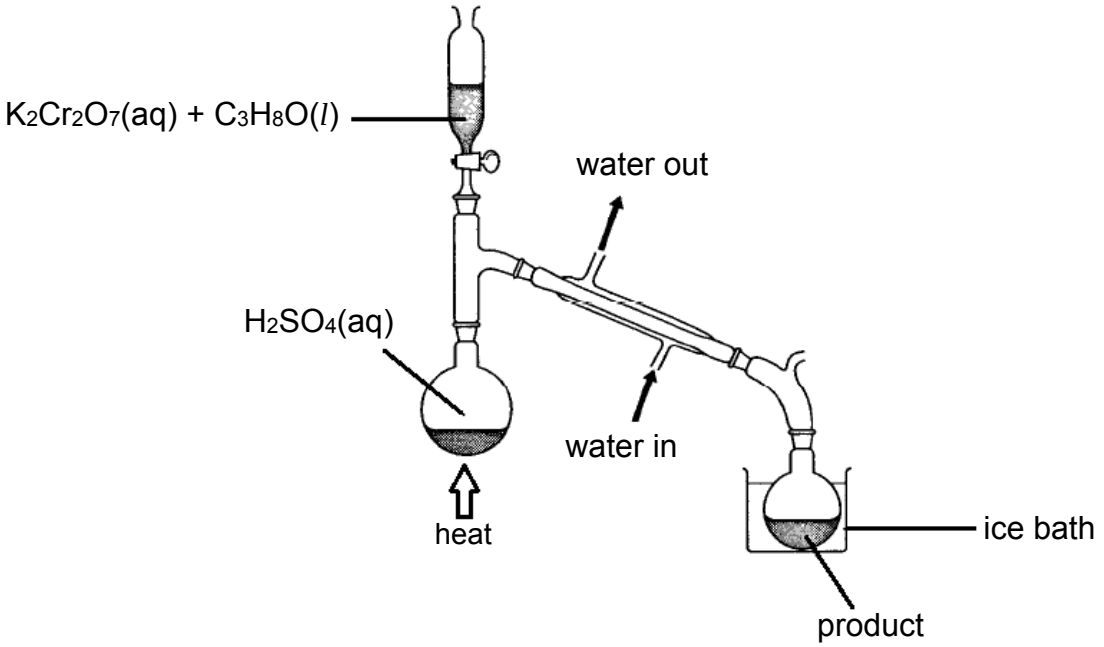
(ii) State the type of reaction for the formation of **S** from CH_3COCH_3.

type of reaction ..... [1]

[Total: 10]

4 A student was given the following instructions for the oxidation of an alcohol, C_3H_8O. However, the structure of the alcohol was unknown.

1. To 20 cm^3 of water in a round bottom flask, carefully add 5 cm^3 of concentrated sulfuric acid and set up the distillation apparatus as shown below.



2. Make up a solution containing 47.2 g of potassium dichromate(VI), $K_2Cr_2O_7$, in a 15 cm^3 of water, add 18.0 g of the alcohol, C_3H_8O, and pour this mixture into the dropping funnel.

3. Boil the acid in the flask. Add the mixture from the dropping funnel at such a rate that the product is slowly collected.

4. Re-distil the product and collect the fraction that boils between 48°C and 50°C.

The balanced equation of the reaction is

$$3C_3H_8O + K_2Cr_2O_7 + 4H_2SO_4 \longrightarrow 3\ C_3H_6O + Na_2SO_4 + Cr_2(SO_4)_3 + 7H_2O$$

(i) State the colour change that the student would observe during the reaction.

from……..… to ……

[1]

(ii) Calculate the amount of $K_2Cr_2O_7$ and C_3H_8O used. Hence, determine the limiting reagent.

[2]

(iii) The student obtained 5.22 g of the carbonyl compound, C_3H_6O. Calculate the percentage yield of the product obtained by the student assuming that the reaction goes to completion.

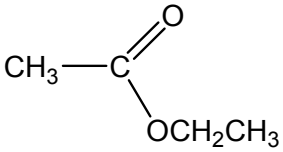
[2]

(iv) Identify the possible isomers of the alcohol, C_3H_8O.

[2]

(v) **Use the table of typical proton chemical shift value (δ) relative to T.M.S.=0 in the *Data Booklet* to answer this question.**

Nuclear magentic resonance can be used to identity functional groups in organic compounds. For example, ethyl ethanoate shows a chemical shift at 2.0 ppm.



ethyl ethanoate

An impure sample of C_3H_6O obtained by a student was analysed using nuclear magnetic resonance. The nuclear magnetic resonance recorded a chemical shift at 9.0–13.0 ppm.

Identity the functional group present in the impurity. Explain your answer.

functional group present in the impurity …….

reason ……..…….....

...…….....

……...…… [2]

(vi) Based on your answer in **(iv)** and **(v)**, suggest a structure for the alcohol used.

[1]

[Total: 10]

Section B

Answer **two** of the three questions in this section on separate answer paper.

5 **(a)** Ozone is usually made by passing oxygen gas through a tube between two highly charged electrical plates.

$$3O_2(g) \rightarrow 2O_3(g)$$

The reaction does not go to completion, so a mixture of the two gases results.
The concentration of O_3 in the mixture can be determined by its reaction with aqueous KI.

$$O_3 + 2KI + H_2O \rightarrow I_2 + O_2 + 2KOH$$

The iodine formed can be estimated by its reaction with sodium thiosulfate.

$$2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI$$

When 500 cm^3 of an oxygen/ozone gaseous mixture at s.t.p. was passed into an excess of aqueous KI, and the iodine titrated, 15.0 cm^3 of 0.100 mol dm^{-3} $Na_2S_2O_3$ was required to discharge the iodine colour.

(i) Calculate the amount in moles of iodine produced. [1]

(ii) Hence calculate the percentage of O_3 in the gaseous mixture. [2]

(b) Carbon exists in two allotropic forms, diamond and graphite.

(i) Explain, in terms of structure and bonding, why diamond and graphite have very high melting points. [1]

(ii) State and explain how diamond and graphite differ in their electrical conductivity. [2]

(c) Like carbon, phosphorus has different allotropes, exhibiting different colours and properties. Phosphorus reacts with chlorine to produce two chlorides, PCl_3 and PCl_5, depending on the amount of chlorine present during the reaction.

However, nitrogen reacts with chlorine to form only one chloride, NCl_3, although nitrogen is in the same group as phosphorous.

(i) Suggest a reason why PCl_5 exists but NCl_5 cannot be formed. [2]

(ii) At 298 K, PCl_5 is a solid, while PCl_3 is a liquid.

Account for the difference in physical states of the two phosphorus chlorides at room temperature. [2]

(d) PCl_5 is used as a reagent in organic reactions with alcohols. It was used in the first step of the following reaction.

$$CH_3CH_2CH_2OH \xrightarrow[\textbf{Step I}]{PCl_5} \textbf{E} \xrightarrow[\textbf{Step II}]{} CH_3CH{=}CH_2$$

(i) Draw the structure of **E** and state the type of reaction taking place in **Step I**. [2]

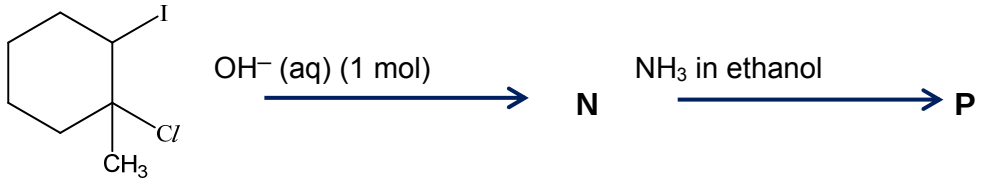
(ii) Suggest the reagents and conditions for **Step II**. [1]

(e) Halogenoalkanes, R*X* (where *X* = C*l*, Br, I), are used widely in the industry to produce organic compounds commercially. Halogenoalkanes can undergo hydrolysis by heating under reflux with aqueous sodium hydroxide.

(i) Write a balanced equation to show the reaction between 1-bromopropane and aqueous sodium hydroxide. [1]

(ii) Describe and explain the relative reactivity of chloro and iodo–compounds with respect to hydrolysis. [2]

(iii) Hence, predict the outcome of the following transformation on **M**, a dihalogeno compound, by drawing the structures of the intermediate **N** and product **P**.

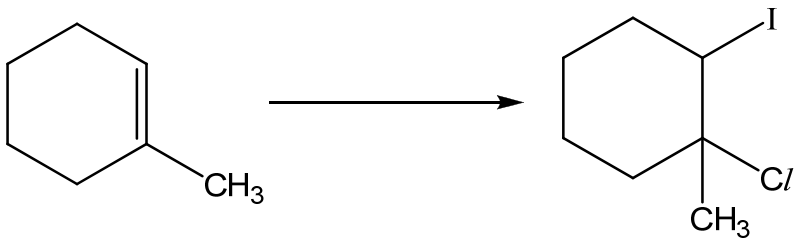


M

[2]

(iv) Compound **M** can be synthesized from compound **L**.

Suggest suitable reagents and conditions needed to perform this conversion.



L **M**

[1]

(v) Halogenoalkanes can also be synthesised from alkanes. Suggest with reasoning why this method of synthesis is not reliable. [1]

[Total: 20]

6 (a) **W**, **X** and **Y** are three consecutive period 3 elements in the periodic table. **Z** is an isotope of one of these elements.

The table below provides information on the number of protons, neutrons and electrons in species of **W**, **X**, **Y** and **Z**.

	protons	neutrons	electrons
W	15	16	15
$\mathbf{X^{2-}}$	16	17	***q***
Y	17	18	17
$\mathbf{Z^-}$	17	17	18

(i) State the value of ***q***. [1]

(ii) Identify the element, **W**, **X** or **Y**, that is isotopic to **Z**. Explain your answer. [2]

The first nine successive ionisation energies, in kJ mol^{-1}, of an unknown Period 3 element are given in the following table.

1st	2nd	3rd	4th	5th	6th	7th	8th	9th
1251	2298	3822	5159	6542	9362	11018	33604	38600

(iii) Use the information given above to deduce the identity of this element, and explain your answer. [2]

(b) Methanol is an important alcohol used in fuel mixtures, making methyl esters and oxidation to methanol (formaldehyde) to make urea–formaldehyde resin glues.

Methanol is manufactured industrially from carbon monoxide and hydrogen gas in an enclosed system according to the following reaction.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -90 \text{ kJ mol}^{-1}$$

The reaction is typically subjected to the following industrial conditions.

pressure	50 MPa
temperature	250 °C
catalyst	copper–zinc oxide mixture

(i) Define the term dynamic equilibrium. [1]

(ii) Suggest the effect of the high pressure under industrial conditions and catalyst has on

- the position of equilibrium
- the rate of reaction

[3]

(iii) The reaction is performed at a moderately high temperature of 250 °C. Suggest why a low temperature is not used industrially instead. [1]

(c) **(i)** Explain in terms of its structure why ethanoic acid is acidic. [2]

(ii) Esters can be synthesise from alcohol and carboxylic acids.

Describe, with **named** reagents and suitable conditions, how you would carry out the reaction to synthesise methyl ethanoate. [2]

(iii) Explain why benzene undergoes substitution, instead of addition, with chlorine, in the presence of the halogen carrier $AlCl_3$. [2]

(d) Describe **two** tests that could distinguish between propanoic acid and propanone.

In each case you should state the reagent and conditions you would use and the observations you would make. [4]

[Total: 20]

7 **(a)** Hydrogen is used in large quantities in industry to convert nitrogen into ammonia, for use in fertilizers. One method of manufacturing hydrogen is to pass methane and steam over a heated nickel catalyst.

$$CH_4\,(g) + H_2O\,(g) \longrightarrow CO\,(g) + 3H_2\,(g) \qquad \Delta H_1 = +206\ kJ\ mol^{-1}$$

(i) Use the value of ΔH_1 above, and bond energy values from the Data Booklet, to calculate the total bond energy in the carbon monoxide molecule. [2]

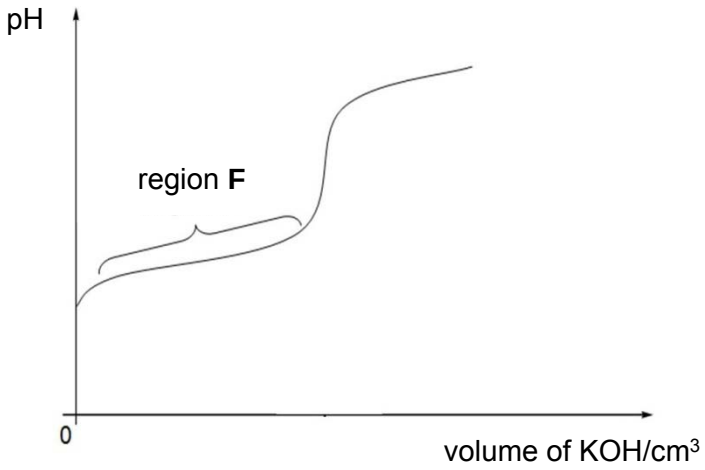
(ii) Use the following data to calculate the enthalpy change of combustion of hydrogen gas.

$$\Delta H_c\,[CO(g)] = -283\ kJ\ mo^{-1}$$
$$\Delta H_c\,[CH_4(g)] = -891\ kJ\ mol^{-1}$$

[2]

(b) Explain how and why the lattice energies of magnesium oxide and magnesium chloride have different numerical values. [2]

(c) 25.0 cm^3 of butanoic acid, $CH_3CH_2CH_2COOH$, was titrated against 0.20 mol dm^{-3} of KOH and the following titration curve was obtained.



(i) The following equilibrium exists within a sample of butanoic acid.

$$CH_3CH_2CH_2COOH\,(aq) \rightleftharpoons CH_3CH_2CH_2COO^-\,(aq) + H^+\,(aq)$$

Write a K_c expression for the above equilibrium. [1]

(ii) Given that the initial pH of butanoic acid is 2.76, calculate the concentration of H^+ ions present. [1]

(iii) The butanoic acid used in this titration has a concentration of 0.196 mol dm^{-3}.

Use your answer in **(c)(i)** and **(c)(ii)** to calculate the value of K_c. [2]

(iv) Region **F** contains a *buffer solution* made up of $CH_3CH_2CH_2COOH$ and $CH_3CH_2CH_2COO^-$.

Explain what is meant by a *buffer solution*. [1]

(d) Reactions with nitrile ions are useful ways of increasing carbon chain of organic compounds.

Halogenoalkane and carbonyl compounds undergo two different reactions with nitrile ions. Using chlorobutane and butanal as example, write an equation for **each** one of the reaction, give the reagents and conditions and identify the type of reaction that occur. [6]

(e) Using the chlorides of aluminium and silicon, describe their reactions with water. Write equations where appropriate to support your answers. [3]

[Total: 20]

END OF PAPER

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