ANDERSON JUNIOR COLLEGE
2016 JC2 Preliminary Examinations
Higher 1

CANDIDATE NAME

PDG _____ / 15

CHEMISTRY 8872/02

Paper 2 **16 September 2016**

2 hours

Candidates answer **Section A** on the Question Paper.

Additional Materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and PDG on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate answer paper.

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	
Paper 1 (33%)	**/ 30**
Paper 2 Section A	
Q 1	
Q 2	
Q 3	
Q 4	
Paper 2 Section B	
Q ___	
Q ___	
Paper 2 (67%)	**/ 80**
Overall	**%**
Grade	

This document consists of **17** printed pages.

Section A

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

1 (a) Data of four species **A**, **B**, **C** and **D** are given in the table below.

species	mass number	number of neutrons
A	60	32
B	63	34
C	64	33
D	66	37

(i) Identify the two species that are isotopes of the same element.

……..... [1]

(ii) Suggest the identity of the element in **(a)(i)** and write its full electronic configuration.

……..... [1]

(b) (i) Complete the table below for each of the sub–atomic particles.

sub–atomic particles	relative mass	relative charge
proton		
neutron		
electron		

[1]

(ii) Some radioactive isotopes emit beta particles and are said to undergo beta decay. In a beta decay, a neutron in the nucleus spontaneously changes to a proton and a high energy electron is emitted which forms the beta particles.

^{3}He is one such isotope that undergoes beta decay forming a new element **E**, as shown by the equation below.

$$^{3}\text{He} \longrightarrow \mathbf{E} + {}^{0}_{-1}\text{e}$$

Write the notation showing the mass number and atomic number of **E**, and hence identify the element.

……..... [1]

(c) The table shows the first three ionisation energies (I.E.) for elements **W**, **X**, **Y** and **Z** from Period 3.

	1st I.E. / kJ mol^{-1}	2nd I.E. / kJ mol^{-1}	3rd I.E. / kJ mol^{-1}
W	1251	2300	3820
X	496	4560	6910
Y	738	1450	7730
Z	1000	2250	3360

(i) Write an equation to represent the second ionisation energy of **Z**.

……..... [1]

(ii) State, with a reason, which of the elements has the **smallest** atomic radius.

……..... [1]

(iii) What is the expected oxidation state for the most common ion of element **X**?

……..... [1]

(iv) Suggest the formulae of the compounds formed when **Y** is burnt separately in oxygen and nitrogen.

……. [1]

(v) Based on your answers above, suggest if aluminium is among the four elements. Explain your answer.

……..... [2]

[Total: 10]

2 The hydrides of light metals are attractive for hydrogen storage because they can store a high weight percentage of hydrogen in a small volume. For example, $NaAlH_4$ can release 56 % of its mass as H_2 upon decomposing to NaH(s), Al(s) and H_2(g). $NaAlH_4$ possesses both covalent bonds, which hold the polyatomic anion together, and ionic bonds.

(a) (i) Write a balanced equation for the decomposition of $NaAlH_4$.

.....

[1]

(ii) Draw a dot–and–cross diagram for the AlH_4^- ion.

[1]

(b) The table below shows three compounds $AlCl_3$, $SiCl_4$ and PCl_3.

Complete the table below for the pH of the resulting solution when each of the chlorides are reacted with water. Write the equation to show the reaction with water, if any.

compound	pH of solution formed	equation to show reaction with water, if any
$AlCl_3$		
$SiCl_4$		
PCl_3		

[3]

(c) Sulfur will combine separately with carbon, hydrogen and sodium to form carbon disulfide (CS_2), hydrogen sulfide (H_2S) and sodium sulfide (Na_2S) respectively.

compound	electrical conductivity	melting point / K	M_r
CS_2	nil	162	76
H_2S	nil	187	66
Na_2S	good, in molten state	1450	78

(i) Explain, in terms of structure and bonding, why the melting point of Na_2S is much higher than that of CS_2 and H_2S.

.....

.....

.....

.....

[2]

(ii) By considering the numbers of bonding and non–bonding electron pairs, draw diagrams in the boxes below to show the likely shapes of CS_2 and H_2S.

In your diagrams, clearly indicate the values of the bond angles.

CS_2	H_2S

[2]

(iii) Under suitable conditions, one mole of A*l*C*l*$_3$ reacts with one mole of H_2S to form a single product **H**. Draw a diagram in the box below to show the likely shape of the product **H**.

product **H**

[1]

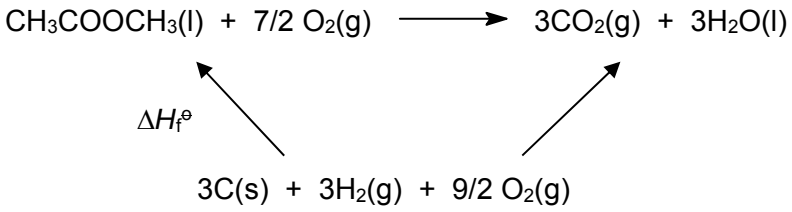
[Total: 10]

3 (a) (i) Write an equation, including state symbols, to represent the standard enthalpy change of combustion of hydrogen.

……..... [1]

(ii) Use the energy cycle below and the standard enthalpy changes of combustion, $\Delta H_c^{\ominus}$, in the table to calculate the standard enthalpy change of formation, $\Delta H_f^{\ominus}$, of methyl ethanoate, CH_3COOCH_3.

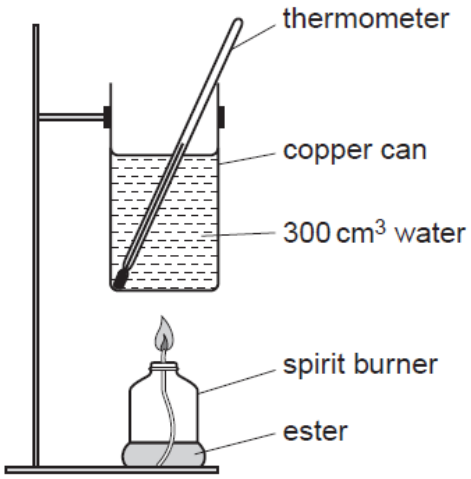
	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
carbon	–393.5
hydrogen	–285.8
methyl ethanoate	–1592.1



$\Delta H_f^{\ominus}$ of methyl ethanoate: …….

[2]

(b) A student used the apparatus shown to carry out experiments to determine the standard enthalpy change of combustion of methyl ethanoate, CH_3COOCH_3.



Mass of copper can = 250 g

An initial experiment was carried out using methyl ethanoate. This ester was burnt in a spirit burner underneath a copper can so that the flame from the burner heated 300 cm^3 of water in the can. It was found that 0.980 g of ester was required to raise the temperature of the water in the can by 10.0 ^oC.

(i) Calculate the total heat energy **in kJ** gained by the water and the copper can in this experiment. The specific heat capacities of water and copper can are 4.18 J g^{-1} K^{-1} and 0.384 J g^{-1} K^{-1} respectively. Take the density of water to be 1.00 g cm^{-3}.

[2]

(ii) Using the $\Delta H_c^{\ominus}$ of methyl ethanoate given in the table on page 7, calculate the total theoretical heat energy **in kJ** released by the mass of methyl ethanoate burnt in this initial experiment.

[1]

(iii) Calculate the percentage efficiency of heat transfer in this experiment.

[1]

(iv) A similar experiment with ethyl ethanoate, $CH_3COOCH_2CH_3$, produced the following results.

Mass of ethyl ethanoate burnt = 0.948 g
Increase in temperature of water = 11.5 ^oC

Using your answer to **(b)(iii)**, calculate the most accurate possible value for the standard enthalpy change of combustion of ethyl ethanoate, $CH_3COOCH_2CH_3$ (M_r = 88).

[2]

(v) An important property of esters as a potential fuel is the energy released on combustion of per gram of fuel.

Calculate the total energy released per gram of ethyl ethanoate burnt.

[1]

[Total: 10]

4 The kinetics of the reaction between a bromoalkane (RBr) and an aqueous alkali were investigated at 323 K. The following data were obtained.

experiment	initial [RBr] / mol dm^{-3}	initial $[OH^-]$ / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	0.005	0.10	4.0×10^{-4}
2	0.015	0.10	1.2×10^{-3}
3	0.010	0.20	8.0×10^{-4}
4	0.018	0.30	x

(a) (i) Deduce the order of reaction with respect to RBr and to OH^-.

[2]

(ii) Hence write the rate equation for the reaction.

……...

[1]

(iii) Calculate the initial rate, x, in experiment 4.

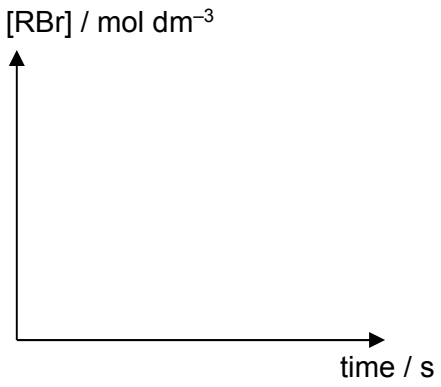
[1]

(iv) Calculate the rate constant for the reaction, including units.

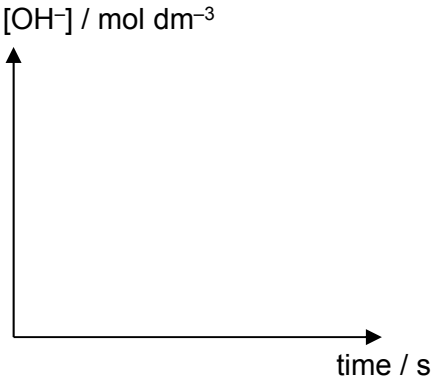
[2]

(b) (i) Sketch the shapes of the lines you would expect for the following two graphs. Include essential details on the graph(s), where appropriate.

Graph **A**



Graph **B**



[3]

(ii) Sketch a second line on Graph **B** above to show how the [OH$^-$] would be affected if the reaction is carried out at a higher temperature. Label this line clearly as "**(ii)**".

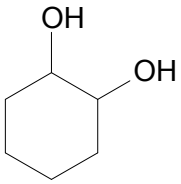
[1]

[Total: 10]

Section B

Answer **two** questions from this section on separate answer paper.

5 **(a)** The boiling points of some organic compounds are given in the table below.

	compound	M_r	boiling point / °C
A	2–methylpropane	58	–11.7
B	butane	58	–1.0
C	chloropropane	78.5	46.6
D	ethanol	46	78.4
E	cyclohexanol	100	160.8
F	 1,2–cyclohexadiol	116	117.0

Describe and explain the difference in boiling points for the following pairs of compounds: (I) **A** and **B**; (II) **B** and **C**; (III) **D** and **E**; (IV) **E** and **F**.

[8]

(b) Ethene can react with bromine to form 1,2–dibromoethane.

(i) Describe the bonding between the two carbon atoms in ethene in terms of orbital overlap. You may draw a diagram to illustrate your answer.

[2]

(ii) What conditions are needed for the reaction to occur? [1]

(iii) Write an equation for this reaction. [1]

(c) Suggest structures for the following hydrocarbons that meet the respective descriptions:

(i) Contains two sp^2–hybridised carbon atoms and two sp^3–hybridised carbon atoms [2]

(ii) Contains only four sp^2–hybridised carbon atoms [2]

(iii) Contains two sp–hybridised carbon atoms and two sp^2–hybridised carbon atoms [2]

You should label clearly the **type of hybridisation** and **bond angle** with respect to each carbon atom in your structures.

(d) At high temperatures inside the car engines, nitrogen and oxygen react to form the oxides of nitrogen which contribute to acid rain and photochemical smog.

State **two** other pollutants from internal combustion engines and their harmful effects to human beings and the environment.

[2]

[Total: 20]

6 **(a)** Compounds **A** – **D** are solvents which are commonly used in paint removers.

$CH_3CH_2CH(OH)CH_3$ **A**	$CH_3CH_2CH_2CHO$ **B**
$CH_3COCH_2CH_3$ **C**	$(CH_3)_3COH$ **D**

(i) Each of the above compounds, **A** – **D**, is treated with the following reagents in separate test–tubes.

I Tollens' reagent

II 2,4–dinitrophenylhydrazine

III alkaline aqueous iodine

Describe the observations (for both positive tests and negative tests) in each of the test–tubes. You may find it helpful to present your answers in a table format.

[6]

(ii) Suggest a simple chemical test, using reagents **not** stated in **(a)(i)**, to distinguish each pair of compounds below. State the reagents and conditions for the tests, and describe the observations. Write the structural formula of any organic product formed in each case.

1. **A** and **D**
2. **C** and **D**

[6]

(b) **(i)** Write balanced equations for the complete combustion of compound **A**, $CH_3CH_2CH(OH)CH_3$, and compound **B**, $CH_3CH_2CH_2CHO$.

[2]

(ii) Use the bond energy values given in the *Data Booklet* to calculate the standard enthalpy change of combustion, ΔH_c, for each of the compounds **A** and **B**.
[Use a value of 805 kJ mol^{-1} for the bond energy of C=O in CO_2].

Hence deduce which compound releases a greater amount of heat energy upon complete combustion.

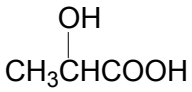
[5]

(iii) Suggest a reason why the ΔH_c values you have calculated in **(b)(ii)** are only estimated values for the combustion of each compound.

[1]

[Total: 20]

7 **(a)** Lactic acid is often known as an alpha–hydroxy acid (AHA) with the structure shown below. Both the acid and its conjugate base, lactate, play very important roles in our daily lives.



lactic acid

(i) State what is meant by a *Bronsted acid* and a *Bronsted base*. [1]

(ii) An aqueous solution of 0.10 mol dm^{-3} lactic acid has a pH of 2.4. Use the data given to deduce whether lactic acid is a strong or weak Bronsted acid.

[2]

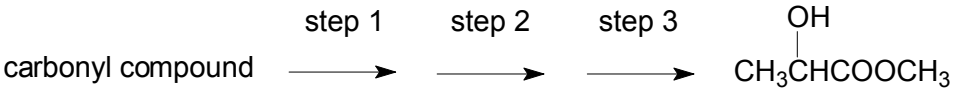
(iii) State what is meant by a *buffer solution*. [1]

(iv) Explain, using equations, why an aqueous mixture of lactic acid and sodium lactate can act as a buffer solution

(I) on the addition of acid,
(II) on the addition of alkali.

[2]

(b) Starting from a suitable carbonyl compound of your choice and using lactic acid as an intermediate, devise a **3–stage** synthesis of compound **A**.



compound **A**

Suggest reagents and conditions for each step and draw the structural formula of every intermediate compound. You may present your answer in a flow diagram.

[6]

(c) Nitrosyl chloride, NO*Cl*, decomposes at high temperatures to give nitric oxide and chlorine as shown.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g) \qquad \Delta H^{\ominus} > 0$$

(i) Write an expression for the equilibrium constant, K_c, for the above reaction. [1]

(ii) In a 2 dm^3 flask, 4.00 mol of NO*Cl* was heated at 300 °C. When equilibrium was established, 0.60 mol of Cl_2 was formed. Determine the K_c for this reaction, giving its units.

[4]

(iii) Predict, with reasoning, how the position of equilibrium might be affected if the following changes are made:

1. a catalyst is used,
2. the temperature is increased to 400 ^{o}C.

[3]

[Total: 20]