RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION

CANDIDATE NAME	
CLASS	
CENTRE NUMBER	S 3 0 4 4
INDEX NUMBER	

H2 CHEMISTRY 9729/02

Paper 2 Structured Questions

12 Sep 2018

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Write your name, class and index number in the spaces at the top of this page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

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

A Data Booklet is provided.

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

PAPER 2	
QUESTION 1	9
QUESTION 2	9
QUESTION 3	8
QUESTION 4	14
QUESTION 5	12
QUESTION 6	10
QUESTION 7	13
Units	
s.f.	

PAPER 1	PAPER 2	PAPER 3	TOTAL	PAPER 4	GRADE
30	75	80	185	55	

This paper consists of **20** printed pages.

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

1 Magnesium, aluminium**, W** and **X** are 4 different elements in the 3rd Period. The following are some of their properties:

The chloride of **W** dissolves in water to give a strongly acidic solution and the oxide of **W**.
The chloride of **X** reacts with ethanoic acid to form ethanoyl chloride as one of the products.

(a) Identify the elements, **W** and **X**, and write the balanced equations for the reactions described above.

W: …………………………

Chloride of **W** dissolved in water (equation):

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X: …………………………

Chloride of **X** reacting with ethanoic acid (equation):

…………………………………………………………………………………………

[2]

(b) Aluminium oxide is a white solid that is soluble in NaOH(aq) to give a colourless solution.

(i) Write a balanced equation, with state symbols, to describe the reaction of aluminium oxide with NaOH(aq).

………………………………………………………………………………………… **[1]**

(ii) Describe the observations made when HC*l*(aq) is carefully added to this colourless solution, until HC*l*(aq) is in excess.

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(c) State and explain how the decomposition temperature of $BaCO_3$ compares with that of $MgCO_3$.

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(d) Explain why the 1^{st} ionisation energy of aluminium is of lower magnitude compared to that of magnesium.

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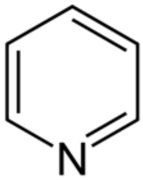
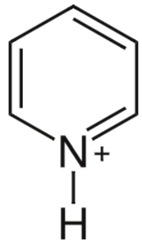
[Total: 9]

2 Pyridine C_5H_5N is a weak alkali with a distinctive, unpleasant fish-like smell. Pyridine reacts readily with hydrochloric acid to form pyridinium chloride only. Pyridinium chloride is commercially available in a form of 98.0% purity by mass.



pyridine



pyridinium

Pyridinium chloride has a pK_a value of 5.25.

(a) Calculate the mass of 98.0% pyridinium chloride that must be added to 1.00 dm^3 of water to give a solution of pH 3.5.

(You may assume no change in volume of solution upon addition of the salt.)

[3]

(b) Calculate the pH of the reaction mixture when 5.00 cm^3 of 0.0125 mol dm^{-3} hydrochloric acid is added to 25.00 cm^3 of 0.100 mol dm^{-3} of pyridine.

[3]

(c) With the aid of **two** equations, explain how a solution of pyridinium chloride and pyridine can control pH.

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[Total: 9]

3 Nitrosoyl chloride, NOC*l*, is a yellow gas that can be formed between nitryl chloride and nitric oxide in the following reversible reaction:

$$NO_2Cl(g) + NO(g) \rightleftharpoons NOCl(g) + NO_2(g) \qquad \Delta H \text{ is negative}$$

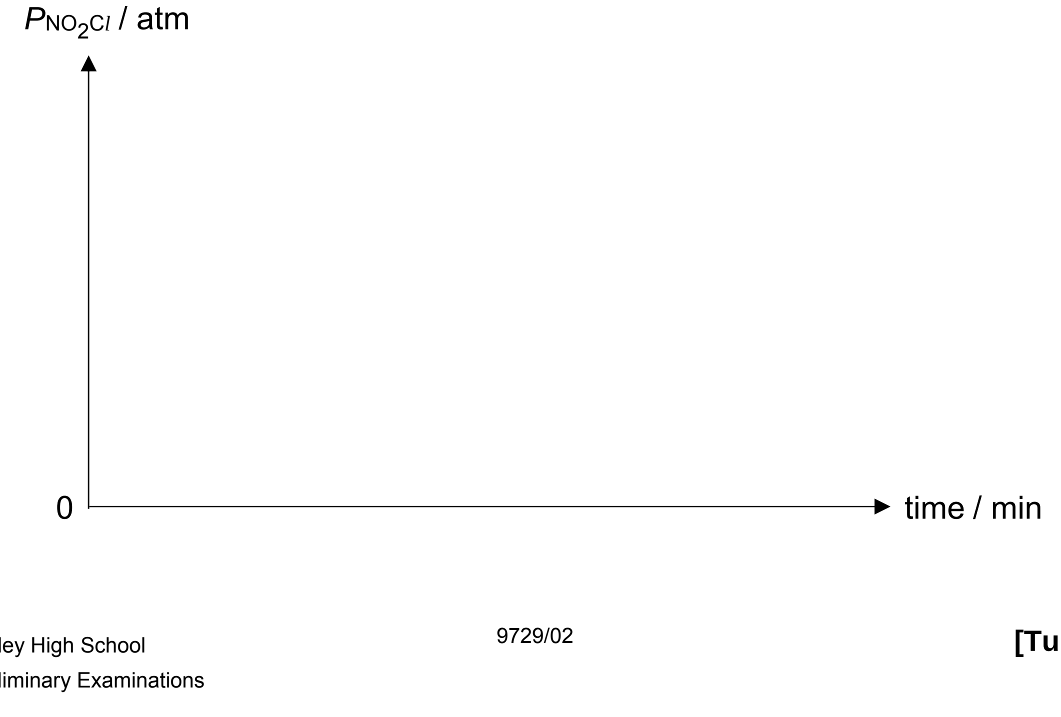
(a) A 3:1 molar ratio mixture of NO_2Cl(g) and NO(g), at a total initial pressure of 5 atm, was allowed to react in a closed vessel at 800 K. When equilibrium was reached at time $\boldsymbol{t_1}$, the partial pressure of NO_2Cl was found to be 2.90 atm.

Calculate the value of the equilibrium constant, K_p, of the reaction at 800 K.

[2]

(b) At time $\boldsymbol{t_2}$, more NO_2Cl gas was introduced into the vessel at 800 K, causing the partial pressure of NO_2Cl to increase to 3.25 atm. The system was allowed to reach equilibrium before the temperature was increased to 1000 K at $\boldsymbol{t_3}$. A new equilibrium was established at $\boldsymbol{t_4}$.

In the pressure-time axes below, sketch the graph that would be observed from time = 0 to time = $\boldsymbol{t_4}$, clearly indicating the values of the partial pressure of NO_2Cl at time = 0, $\boldsymbol{t_1}$ and $\boldsymbol{t_2}$.



[2]

(c) Given that nitrogen is the central atom, draw the dot-and-cross diagram for NOC*l*.

[1]

(d) NOC*l* reacts with $CH_3CH{=}CH_2$ to give a product as predicted by Markovnikov's rule. When the organic product is heated with NaOH(aq), followed by acidification and addition of $AgNO_3$(aq), a white precipitate is obtained.

Given that the oxidation state of chlorine in NOC*l* is +1, state and draw the mechanism for the reaction between NOC*l* and $CH_3CH{=}CH_2$.

[3]

[Total: 8]

4 **(a)** Sucrose, or table sugar, is the most common natural food sweetener. In acidic medium, sucrose is readily hydrolysed to a mixture of glucose and fructose. The reaction is also acid-catalysed.

$$\underset{\text{(sucrose)}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+(aq)} C_6H_{12}O_6 + \underset{\text{(fructose)}}{C_6H_{12}O_6}$$

A series of experiments was carried out at room temperature to investigate the kinetics of this reaction, using 0.850 mol dm^{-3} sucrose solution and 1.23 mol dm^{-3} hydrochloric acid.

Expt	Volume of sucrose / cm^3	Volume of HC*l* / cm^3	Volume of water / cm^3	Initial rate of reaction / mol dm^{-3} min^{-1}
1	20	30	0	1.77×10^{-3}
2	20	20	10	1.18×10^{-3}
3	10	30	10	8.85×10^{-4}
4	40	20	10	?

(i) Using the data given above, determine the order of reaction with respect to sucrose and HC*l*.

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(ii) Hence, write the rate equation and deduce the rate constant of the reaction, stating its units.

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(iii) Using your answer in **(a)(ii)**, calculate the initial rate of reaction for Experiment 4.

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(b) In bacteria, sucrose is broken down into glucose and fructose by the enzyme, invertase. Experiments were done to measure the rate of the enzyme-catalysed hydrolysis reaction for different concentrations of sucrose.

(i) Sketch a graph to show how the rate of this enzyme-catalysed hydrolysis reaction varies with the concentration of sucrose until sucrose is in large excess.

[1]

(ii) Explain the shape of the graph in **(b)(i)**. In your answer, make reference to the order of reaction with respect to sucrose.

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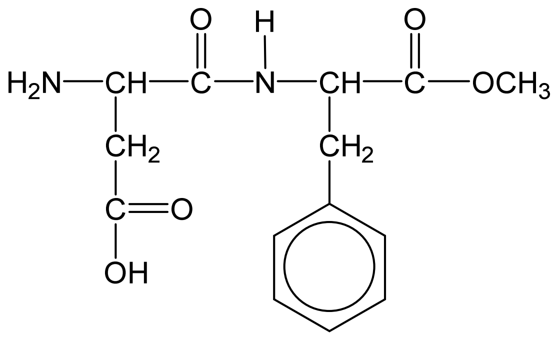
(c) Aspartame, an artificial sweetener, is 200 times sweeter than sucrose.

The structure of aspartame is as follows.



(i) Draw the structure in which aspartame exists in water.

[1]

(ii) Hence, explain why aspartame is soluble in water.

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……………………………………………………………………………………... **[1]**

(iii) Draw the structural formulae of all the organic products formed when aspartame is heated with aqueous NaOH.

Label any chiral carbon in each product with an asterisk.

[3]

[Total: 14]

5 Manganese exhibits the widest range of oxidation states among the 1st set of transition elements from titanium to copper.

In deaerated aqueous solution and in the presence of excess CN^- ions, pale pink $Mn^{2+}(aq)$ forms blue $[Mn(CN)_6]^{4-}$ ion. $[Mn(CN)_6]^{4-}$ ion reacts with 3% solution of hydrogen peroxide to form red $[Mn(CN)_6]^{3-}$ ion.

In the visible spectrum, red is the lowest energy light while violet is the highest energy light.

(a) Explain why transition elements exhibit variable oxidation states.

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(b) Explain why there is a difference in the colour observed for $[Mn(CN)_6]^{4-}$ and $[Mn(CN)_6]^{3-}$ ions.

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(c) Given that:

$$[Mn(CN)_6]^{3-} + e \rightleftharpoons [Mn(CN)_6]^{4-} \qquad E^{\ominus} = -0.24\ V$$

Use the *Data Booklet* to suggest why Mn(III) ion exhibits stronger oxidising power in aqueous solution than in concentrated cyanide solution in terms of

- $E^{\ominus}$ and
- effect of ligand exchange on $E^{\ominus}$.

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(d) The figure below gives the splitting diagram of the d-orbitals in the presence of an octahedral ligand field.

A transition metal complex can exist in a 'high spin' state or in a 'low spin' state.

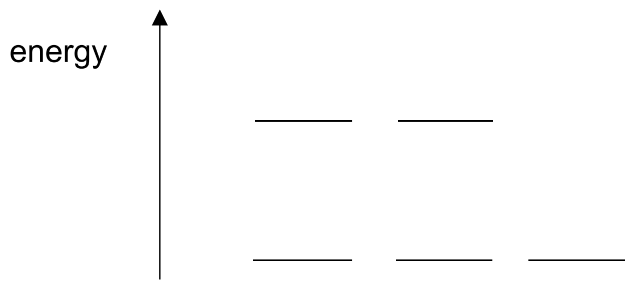
In a 'high spin' state, the electrons occupy all the d-orbtials singly, before starting to pair up in the lower energy d-orbitals.

In a 'low-spin' state, the lower energy d-orbitals are filled first, by pairing up if necessary, before the higher energy d-orbitals are used.

Electrons usually prefer to occupy orbitals singly, rather than in pairs, to minimise coulombic repulsion, also known as the pairing energy.

In this question, only one of the cyanido-complexes of manganese is high-spin.

(i) Using this information, and compare the colour of the cyanido-complexes of manganese, deduce and draw the electronic configuration of the $[Mn(CN)_6]^{3-}$ on the splitting diagram.



[1]

(ii) Explain the spin-state of $[Mn(CN)_6]^{3-}$ in **(d)(i)** in terms of the energy gap between the d-orbitals in both manganese cyanido-complexes and pairing energy.

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(e) Standard reduction potentials are often presented in the form of a potential diagram. The figure below gives the potential diagram of manganese under the condition of $[H^+] = 1 \text{ mol dm}^{-3}$.

$$MnO_4^- \xrightarrow{+0.90\text{ V}} HMnO_4^- \xrightarrow{+2.10\text{ V}} MnO_2$$
$$MnO_4^- \xrightarrow{+1.67\text{ V}} MnO_2$$

(i) Given that $HMnO_4^-$ undergoes disproportionation, construct a balanced equation for the reaction.

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(ii) Calculate $\Delta G^\ominus$ for the reaction.

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(f) It is necessary to carry out reactions involving Mn(II) in deaerated solution as Mn(II) may react with aerated solutions.

Consider the data given below and appropriate values from the *Data Booklet*, calculate the $E^\ominus_{cell}$ values for the oxidation of Mn(II) to Mn(III) in aerated solutions at pH = 0 and pH = 14.

Comment on what the signs of $E^\ominus_{cell}$ indicate about the stability of Mn(II) in acidic and alkaline aerated solutions.

$$Mn(OH)_3(s) + e^- \rightleftharpoons Mn(OH)_2(s) + OH^-(aq) \qquad E^\ominus = +0.18\text{ V}$$

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[Total: 12]

6 Anaerobic digestion is a natural form of waste-to-energy that uses the process of fermentation to break down organic matter in the absence of oxygen. Typically, 50 to 75% of biogas can be combusted, therefore it produces a deep blue flame and can be used as an energy source.

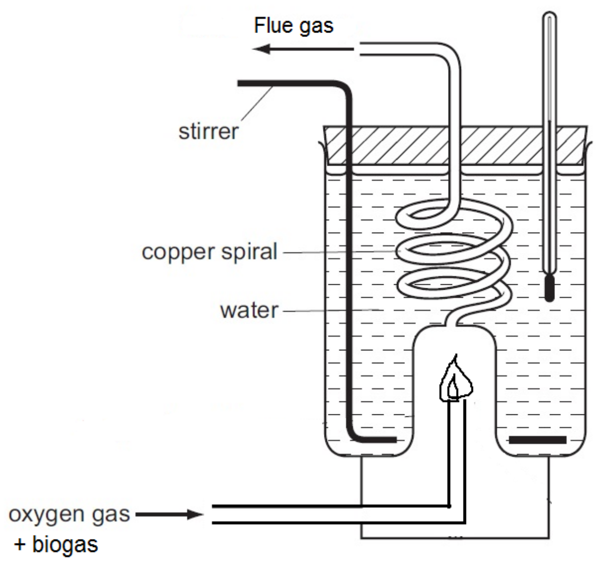
Biogas is primarily made up of methane, along with carbon dioxide. Depending on the type of biodegradable material involved, hydrogen sulphide (H_2S), hydrogen and nitrogen may be produced.

The composition of a sample of biogas by mass is given in the following table, along with the enthalpy change of combustion for each gas.

Biogas component	Percentage mass	ΔH_c / kJ mol^{-1}
methane	72.2	?
carbon dioxide	21.6	0.00
hydrogen sulfide	1.2	– 482
hydrogen	2.7	– 386
nitrogen	2.3	– 43.1

The total energy evolved from the combustion of biogas can be determined using a calorimeter as shown in Figure 6.1.

Figure 6.1



(a) **(i)** The cooled flue gas contains carbon dioxide, sulfur dioxide and nitrogen gas.

Two gases present in the sample of biogas do not react with oxygen. Identify the two gases and explain why they do not react.

Identity of gases: ………………………… and …………………………

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(ii) Write balanced equations to show the reaction for 1 mole of each component of biogas that reacted under standard conditions.

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(iii) An experiment was carried out to determine the fuel value of a sample of biogas using a calorimeter as shown in Figure 6.1. Fuel value is defined as the amount of energy generated by complete combustion of one gram of the fuel.

In this experiment, biogas was mixed with excess oxygen at room temperature and pressure before it was passed into the calorimeter.

Assuming that the efficiency of heat transferred to water is 100%, use the *Data Booklet* and the following information to determine the energy evolved. Hence determine the fuel value of biogas.

Volume of biogas used = 1.00 dm^3

Density of biogas is 6.44×10^{-4} g cm^{-3}

Volume of water heated = 200 cm^3

Density of water = 1.00 g cm^{-3}

Initial temperature of water = 29.6 °C

Maximum temperature of water reached = 64.7 °C

[2]

(iv) Use the information provided, calculate the amount of each gas that combusted. Hence, determine the enthalpy change of combustion of methane.

[2]

(c) To determine the fuel values of biogas, the apparatus in Figure 6.1 can simply be replaced with a beaker of water with lid and a thermometer.

Suggest how the design of the apparatus in Figure 6.1 improves the efficiency of heat transfer to the water.

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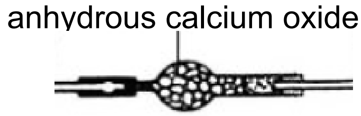
(d) Cooled flue gas was passed through a tube containing anhydrous calcium oxide, as shown in Figure 6.2, before being discharged into the atmosphere.

Figure 6.2



Explain why it is important for the cooled flue gas to be passed through anhydrous calcium oxide.

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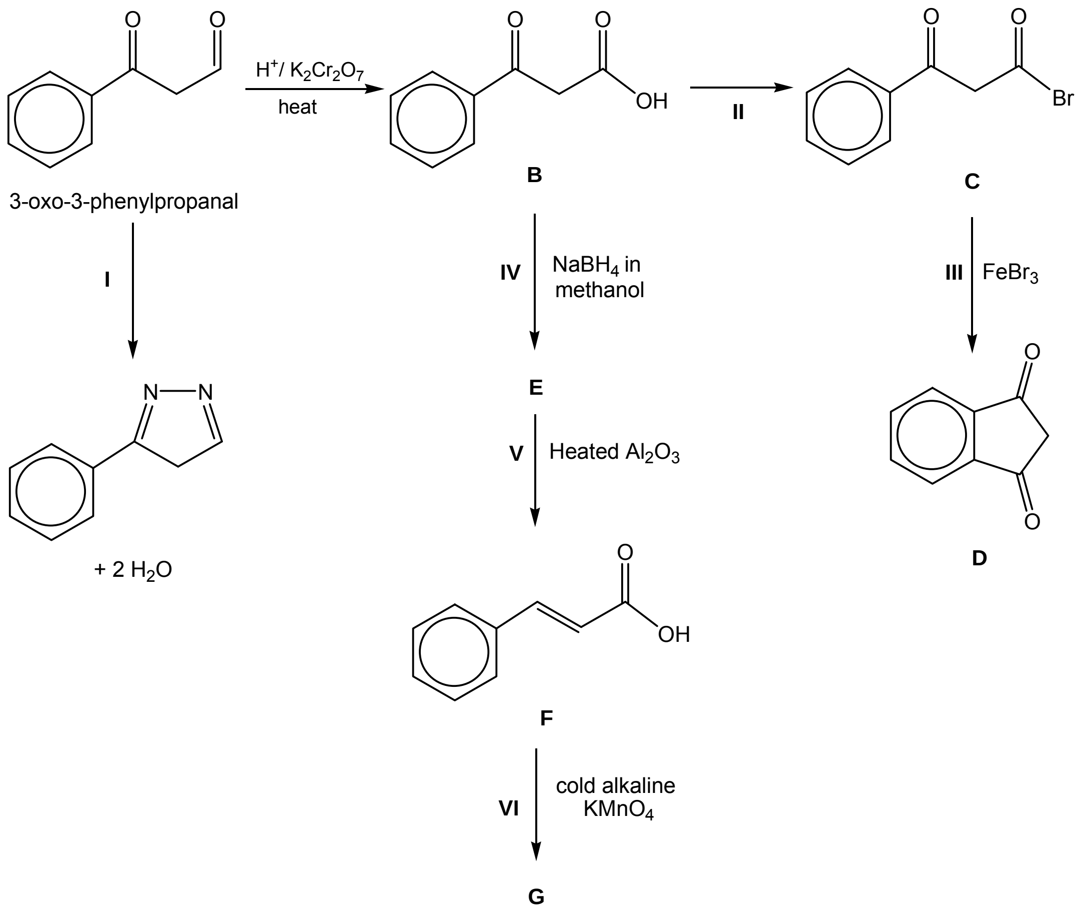
[Total: 10]

7 **(a)** A student carried out a series of tests on 3-oxo-3-phenylpropanal.



(i) Suggest the reagents and conditions required for reactions **I** and **II**.

Reaction **I**: ……………………………………………………………….

Reaction **II**: ………………………………………………………………. **[2]**

(ii) Draw the structures of **E** and **G**.

E	**G**

[2]

(iii) Describe the mechanism for reaction **III**, and provide the name of the mechanism.

[3]

(b) Suggest simple laboratory tests to distinguish between compounds **B**, **C** and **F**. State the expected observations for each compound.

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(c) Describe what the student will observe when 3-oxo-3-phenylpropanal is warmed with Fehling's solution. Write an equation for this reaction.

[Total: 13]

- End of Paper -