Class Adm No

Candidate Name: _____

H

millennia institute

2019 Preliminary Exams
Pre-University 3

H2 CHEMISTRY **9729/02**

Paper 2 Structured Questions **16 Sept 2019**

2 hours

Candidates answer on the Question paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number 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.

Answer **all** questions.

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

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.

Question	1	2	3	4	5	Total
Marks	/7	/23	/16	/14	/15	/75

1 **(a)** Zinc-air batteries worked by oxidising zinc with oxygen from the air. At the cathode, oxygen converts to hydroxide ions. At the anode, zinc reacts with the hydroxide ions to form zincate, $[Zn(OH)_4]^{2-}$.

(i) Construct an ion-electron equation for the reaction that takes place at each electrode under alkaline conditions. [2]

Cathode: ……

Anode: ……

(ii) At 298K, the standard electrode potential of the $[Zn(OH)_4]^{2-}(aq)|Zn(s)$ half-cell is -1.25 V. Calculate the cell voltage using relevant data from the *Data Booklet*. [1]

(iii) Using relevant data from the *Data Booklet*, deduce if oxygen gas can be replaced with chlorine gas. [2]

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(b) Another type of battery known as the nickel-cadmium battery is a type of rechargeable battery using nickel oxide hydroxide and metallic cadmium as electrodes. The electrode reaction equations for the **discharging** process under alkaline conditions is given below.

Cathode: $Cd + 2OH^- \rightarrow Cd(OH)_2 + 2e^-$
Anode: $2NiO(OH) + 2H_2O + 2e^- \rightarrow 2Ni(OH)_2 + 2OH^-$

(i) Construct the overall equation for the reaction that takes place during **charging**. [1]

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(ii) Suggest a disadvantage of using nickel-cadmium battery. [1]

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[Total: 7]

2 Paramagnetism and diamagnetism are different forms of magnetism. Paramagnetic materials are weakly attracted by an externally applied magnetic field and form magnetic fields in the direction of the applied magnetic field. In contrast, diamagnetic materials are repelled from magnetic fields and form magnetic fields in the direction opposite to that of the applied magnetic field.

Transition metals are mostly paramagnetic or diamagnetic. The magnetic property is characterised by the presence of unpaired electrons in paramagnetic compounds and absence of unpaired electrons in diamagnetic compounds.

The table below shows the magnetic property of metal complexes.

Formula of complex	**Magnetic property of complex**
$Fe(CO)_5$	Paramagnetic
$[Fe(H_2O)_6]^{2+}$	Paramagnetic
$[Fe(H_2O)_6]^{3+}$	Paramagnetic
$[ZnCl_4]^{2-}$	Diamagnetic
$[V(H_2O)_6]^{3+}$	
$[Sc(H_2O)_3(OH)_3]$	

(a) **(i)** Write the electronic configurations of V in $[V(H_2O)_6]^{3+}$ and Sc in $[Sc(H_2O)_3(OH)_3]$. [2]

V in $[V(H_2O)_6]^{3+}$: ……

Sc in $[Sc(H_2O)_3(OH)_3]$: ……

(ii) State the magnetic property of $[V(H_2O)_6]^{3+}$ and $[Sc(H_2O)_3(OH)_3]$ in the above table. [1]

(iii) Draw labelled diagrams to show the shapes of the d orbitals of the metal ion in $[V(H_2O)_6]^{3+}$. Include the relative energy of the d-orbitals in the complex. [3]

d-orbitals of lower energy:……..

d-orbitals of higher energy: ……..

(iv) Explain why transition metal can show variable oxidation states. [1]

……

……

(b) Sodium reacts with iron pentacarbonyl to produce a salt known as sodium tetracarbonylferrate, $Na_2Fe(CO)_4$.

$$2Na + Fe(CO)_5 \longrightarrow Na_2Fe(CO)_4 + CO \quad \text{------- eqn (1)}$$

(i) Explain what is meant by the coordination number of a complex using $Fe(CO)_5$ as an example. [1]

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(ii) Draw the structure of $Fe(CO)_5$ and state its shape. [2]

Shape: ……..

(iii) Deduce the oxidising and reducing agent in eqn (1). [2]

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(iv) Explain why carbon monoxide, CO, is poisonous. [2]

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(v) The tetracarbonylferrate dianion acts as a nucleophile and react with alkyl halide by the S_N2 mechanism to form a new C-Fe bond.

$$[Fe(CO)_4]^{2-} + CH_3Br \longrightarrow [Fe(CH_3)(CO)_4]^{-} + Br^{-} \text{ ------- eqn (2)}$$

Suggest a mechanism between $Fe(CO)_4^{2-}$ and CH_3Br. State clearly any intermediates that may be formed and use curly arrows to indicate the movement of electron pairs. [3]

(vi) State the rate equation for the reaction in eqn (2). [1]

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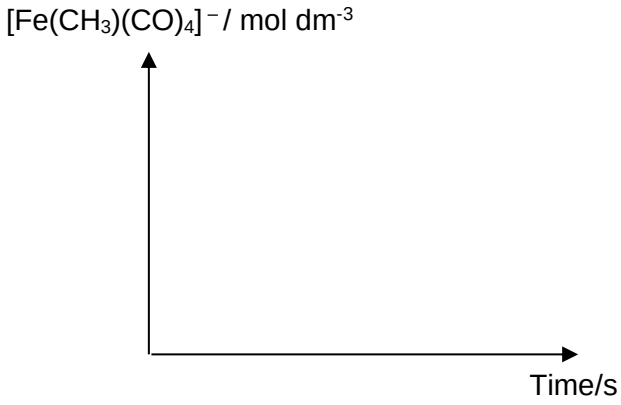
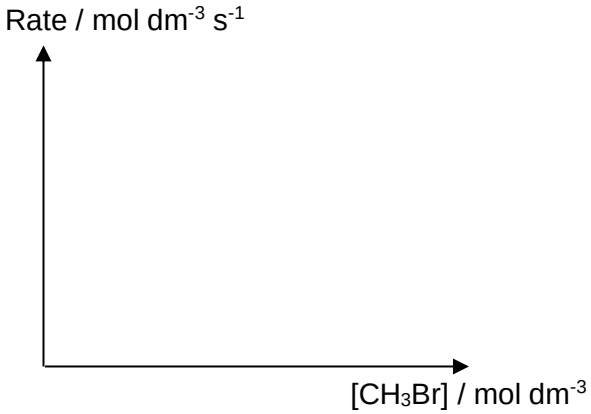
(vii) **I** Sketch the graph of $[Fe(CH_3)(CO)_4]^-$ against time.



II Sketch the graph of rate against $[CH_3Br]$ given that $[Fe(CO)_4]^{2-}$ is in excess.



[2]

(c) The melting point of sodium tetracarbonylferrate, $Na_2Fe(CO)_4$ is lower than that of sodium oxide. With reference to the structure and bonding, explain the difference in melting point.[3]

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[Total: 23]

3 **(a)** Phosgene, $COCl_2$, is essential in the manufacturing of everyday products, including medical products and footwear. Phosgene is produced by combining carbon monoxide and chlorine with a catalyst.

$$CO(g) + Cl_2(g) \rightarrow COCl_2(g)$$

(i) Draw a 'dot-and-cross' diagram of $COCl_2$ and state the bond angle about the central atom. [2]

Bond angle: ……..

(ii) Using relevant data from the *Data Booklet*, construct a fully labelled energy level diagram to calculate the enthalpy change of the above reaction. [3]

(iii) Explain what is meant by the term entropy of a chemical system. [1]

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(iv) Predict, with reasons, the sign of the entropy change of the reaction between CO(g) and Cl_2(g) to form $COCl_2$. [2]

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(v) Hence, state and explain the significance of the sign of the standard Gibbs free energy change when temperature is low. [2]

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(b) Above 200°C, a 2.0 dm^3 cylinder containing gaseous phosgene decomposes to carbon monoxide and chlorine in a dynamic equilibrium according to the following equation:

$$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$$

(i) Predict and explain the effect of a catalyst on the position of the above equilibrium. [1]

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(ii) At 350°C, the percentage dissociation of $COCl_2$ is found to be 45% and the total pressure at equilibrium is 3.5 atm. Calculate the value of K_p at 350 °C. [3]

(iii) Calculate the mass of the carbon monoxide gas that exists inside the cylinder at 350°C. [2]

[Total: 16]

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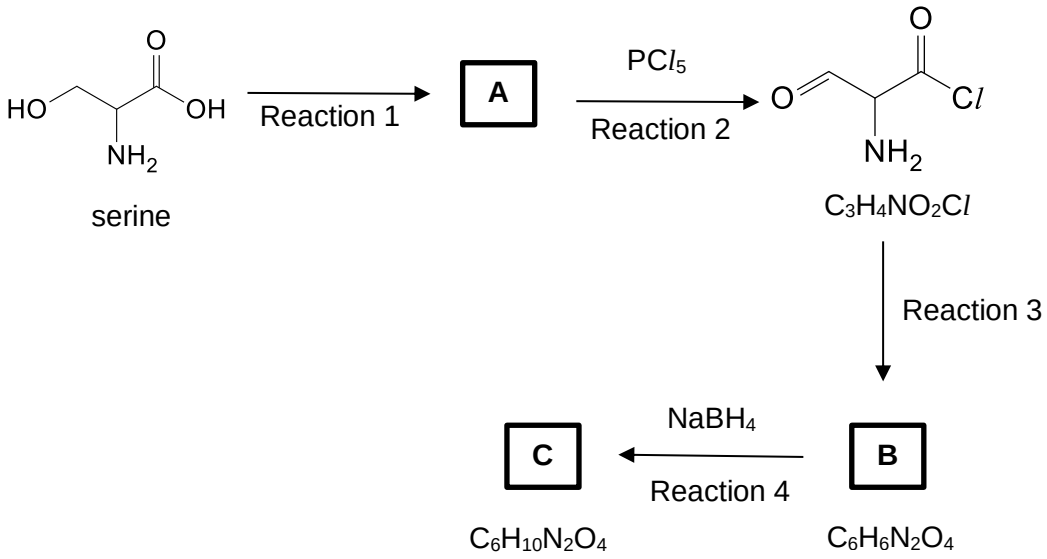
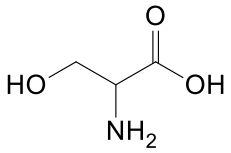
4 Spider silk is a protein fibre. Major amino acids in the silk protein are alanine, serine and glycine. The following reaction scheme involves serine as a starting material.



(a) Explain what is meant by a chiral centre.
Label with an asterisk (*) for any chiral centre that is present in serine. [2]



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(b) Name the functional group common to compounds **B** and **C**. [1]

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(c) Draw the structure of compound **A** and state the reagents and conditions for reaction 1. [2]

A

Reagent and conditions: ……..

(d) Name the type of reaction for reactions 2, 3 and 4. [3]

Reaction 2: ……...

Reaction 3: ……...

Reaction 4: ……...

(e) Draw the structures of compound **B** and **C**. [2]

B **C**

(f) The following table contains the pK_a values of different compounds.

Compound	**pK_a**
Serine	2.21
Propanoic acid	4.87
Phenol	9.95

(i) Suggest a reason why pK_a of propanoic acid is higher than serine. [2]

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(ii) Suggest a reason why pK_a of propanoic acid is lower than phenol. [2]

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[Total: 14]

5 (a) **X** and **Y** are two different elements in Period 3. The following are some of their properties:

- Oxide of **X** is insoluble in water while the aqueous solution of chloride of **X** is weakly acidic.
- Element **Y** conducts electricity and has a lower melting point than element **X**.
- The first ionisation energy of element **X** is lower than that of element **Y**.

(i) Identify the elements, **X** and **Y**. [2]

X: ……

Y: ……

(ii) Write the balanced equation(s) for the reaction when chloride of **X** dissolves in water and state the pH of the solution. [2]

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(iii) Explain why oxide of **X** is insoluble in water. [1]

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(iv) Explain why element **Y** has a lower melting point than element **X**. [2]

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(v) Explain why the first ionisation energy of element **X** is lower than that of element **Y**. [2]

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(b) Sulfur is another period 3 element with a relative atomic mass of 32.09.

There are three naturally occurring isotopes. The relative abundances of the isotopes of sulfur are found to be the following.

Isotope	**% Abundance**
^{32}S	95.0
^{33}S	*a*
^{34}S	*b*

(i) Define the term *relative atomic mass*. [1]

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(ii) Calculate the percentage abundances of isotopes ^{33}S and ^{34}S. [2]

(c) A 2.00 g sample of food additive containing magnesium carbonate is allowed to react with 50 cm^3 of 0.200 mol dm^{-3} aqueous hydrochloric acid. The excess acid required 19.30 cm^3 of 0.100 mol dm^{-3} aqueous potassium hydroxide for complete reaction.

Calculate the percentage of magnesium carbonate that is present in the food additive. [3]

[Total: 15]

END OF PAPER 2

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