Class | Adm No

Candidate Name: _____

millennia institute

2018 End-of-Year Exams
Pre-University 2

H1 CHEMISTRY **8873 / 02**

Paper 2 Structured Questions **11 Sept 2018**

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	Section B	Total
Marks	/15	/10	/15	/9	/11	/20	/80

For Examiners' Use

Section A
Answer all questions in the spaces provided.

1 In acidic solution, bromate(V) ions, BrO_3^-, oxidises bromide ions to bromine. The progress of the reaction may be followed by adding a fixed amount of phenol (an aromatic alcohol) together with methyl red indicator.

The bromine produced during the reaction reacts very rapidly with phenol. When all the phenol is consumed, any excess bromine bleaches the indicator immediately. The initial rate of formation of Br_2 is indicated by the time taken for the bromine to bleach the indicator.

(a) An experiment was carried out four times at room temperature. The total volume of the reaction mixture is the same in all four experiments and the following data were obtained.

Experiment	$[BrO_3^-]$ / mol dm^{-3}	$[Br^-]$ / mol dm^{-3}	Initial rate of formation of Br_2 / mol dm^{-3} s^{-1}
1	0.10	0.10	8×10^{-2}
2	0.10	0.05	4×10^{-2}
3	0.05	0.05	2×10^{-2}
4	0.05	0.10	4×10^{-2}

(i) Determine the order of the reaction with respect to each of the following reactants, showing your working clearly.

I. BrO_3^-

II. Br^-

[3]

(ii) Based on your answer in **(a)(i)**, sketch a concentration-time graph for BrO_3^-.

[1]

For Examiners' Use

(iii) Describe, and explain in molecular terms, how the rate of reaction is affected by an increase in temperature. You should make reference to the Boltzmann distribution in your answer.

……

……

……

……[3]

(b) **(i)** State the oxidation number of the **Br atom** in each of the following substances:

I. BrO_3^- Oxidation number of the Br atom: _____

II. bromide, Oxidation number of the Br atom: _____

III. bromine Oxidation number of the Br atom: _____ [3]

(ii) In a separate experiment, 20.0 cm^3 of 0.0200 mol dm^{-3} BrO_3^- was found to react completely with 80.0 cm^3 of 0.0100 mol dm^{-3} hydroxylamine, NH_2OH. BrO_3^- ions were reduced as shown in the ion-electron equation below.

$$BrO_3^- + 6e^- + 6H^+ \rightarrow Br^- + 3H_2O$$

Given that the original oxidation number of N in NH_2OH was -1, calculate the final oxidation number of N.

[4]

(iii) Based on your answer in **(b)(ii)**, suggest a possible product for the oxidation of hydroxylamine.

.....[1]

[Total: 15]

2 Magnesium and aluminium are elements in Period 3 of the Periodic Table.

(a) State and explain **two** factors that lead to aluminium having a higher melting point than magnesium.

.....

.....

.....[2]

(b) MgO and Al_2O_3 have giant ionic lattice structures.
Explain why the melting point of Al_2O_3 is lower than MgO.

.....

.....

.....[2]

(c) Explain the following observations when separate samples of MgO and Al_2O_3 were added to water. Write suitable equation(s) were appropriate.

I. MgO dissolves slightly in water to give a weakly alkaline solution

II. Al_2O_3 did not dissolve when added to water.

.....

.....

.....

.....

.....[2]

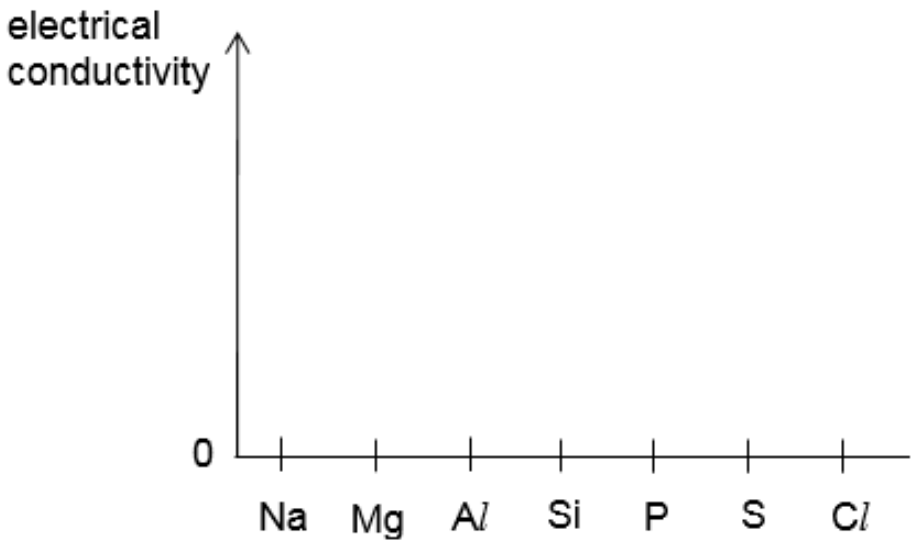
(d) Unlike $MgCl_2$, $AlCl_3$ has the tendency to dimerise to form Al_2Cl_6.
Draw the 'dot-and-cross' diagram of Al_2Cl_6 and explain how the dimer was formed.

……

……

……[3]

(e) Using the axes below, sketch the graph to show the electrical conductivity of the Period 3 elements from Na to Cl.



[1]

[Total: 10]

3 The following abstract is taken from an article from the popular online site '*Chemistry World*'.

Mazda Motor Corporation has unveiled a new generation of catalytic converters that uses 70% to 90% less of the precious metals to purify exhaust emissions. The converters rely on nanoparticles of the catalytic metal, each less than five nanometres across, studded onto the surface of tiny ceramic spheres. The Japanese firm claims this is the first time a catalyst material has been achieved that features single, nanosized precious metal particles embedded in fixed positions.

Automotive catalysts use platinum, rhodium and palladium nanoparticles instead of other larger particles to speed up chemical reactions of pollutants such as nitrogen oxide, carbon monoxide and hydrocarbons, to create non-toxic emissions. Unfortunately, using platinum and palladium nanoparticles can result in negative impacts on human health. Ongoing research suggests that emissions of platinum-group metals from catalytic converters along US highways might be a root cause of an alarming rise in allergies and asthma.

Adapted from ''Catalytic Converters Go Nano' ~ Ned Stafford

(a) (i) By writing a chemical equation, illustrate how automotive catalyst convert pollutants into non-toxic emissions.

…….....[1]

(ii) Suggest why automotive catalysts use nanoparticles instead of larger particles.

…….....

…….....

…….....[2]

(iii) Explain why having platinum or palladium in catalysts can translate into health risks.

…….....

…….....[1]

(b) Gas chromatography (GC) is a type of chromatography used in analytical Chemistry for separating and analysing compounds that can be vaporised without decomposing. The composition of the pollutants in petrol in vehicles can be determined using GC. The exhaust gases are passed through a separating column and the gaseous compounds are being analysed by their interactions with the walls of the column which is coated with a stationary phase (usually a large polymer). These interactions cause the gaseous compounds to be extracted at different timings, known as the retention time of the compounds. If the polarity of the gases and the stationary phase are similar, then there is likely to be a greater interaction between the two. In other words, the retention time will be longer for polar compounds on polar stationary phases and shorter on non-polar stationary phases. Boiling point is another property that affects retention times. If a component has a low boiling point, it is likely to spend more time in the gas phase in the column instead of interacting with the walls of the column. The comparison of retention times gives GC its analytical usefulness.

The following table gives the retention timings of some pollutants.

Compound	**Retention time/ min**
Hydrogen (H_2)	3.0
Carbon monoxide (CO)	14.5
Nitrogen Oxide (NO)	18.8

(i) Account for the difference in retention times for CO and NO.

……

……

……

……[2]

(ii) Carbon monoxide can be oxidised to CO_2.

Draw a dot-and-cross diagram to illustrate the bonding in CO_2. State its shape and bond angle.

Shape: …… Bond Angle: …… [2]

(c) Under room conditions and in the presence of a platinum catalyst, one mole of compound **A**, with molecular formula, C_5H_{10}, requires an equal amount of hydrogen gas for reduction.

(i) Identify the functional group present in compound **A**.

…….....[1]

(ii) Identify the number of sigma and pi bonds in compound **A**.

…….....[2]

(iii) Draw **and** name any **three** possible structures of **A**.

[3]

(iv) Compound **B** can be synthesised from **A**. Given that **B** is a ketone with a relative molecular mass of 58.0 and contains 3 carbon atoms, draw the structure of **B**.

[1]

[Total: 15]

4 But-1-ene, $CH_3CH_2CH=CH_2$, is an important raw material for the production of synthetic rubber. The enthalpy change of combustion, ΔH_c, of but-1-ene can be determined using bond energy values.

(a) (i) Define the term *bond energy*.

……

……[1]

(ii) The bond energy of the C-C bond in butane is 350 kJ mol^{-1}. It was expected that the bond energy of the C=C bond in but-1-ene to be twice that of the C-C bond in butane. However, actual bond energy of the C=C bond in but-1-ene is only 610 kJ mol^{-1}. Account for the difference.

……

……

……[2]

(b) (i) Write an equation to represent the standard enthalpy change of combustion of gaseous but-1-ene.

……[1]

(ii) Hence, use the bond energies in the *Data Booklet* to calculate the standard enthalpy change of combustion of gaseous but-1-ene.

[3]

(iii) In the theoretical calculations in **(b)(ii)**, the physical state of water was assumed to be gaseous. However, in practice, **water vapour condenses into a liquid at room temperature**. State and explain how this would affect the magnitude of your answer in **(b)(ii)**.

……

……

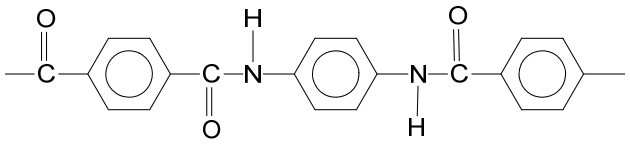
……

……[2]

[Total: 9]

5 (a) Kevlar is a heat-resistant and strong synthetic fibre used in many applications from bicycle tyres to bulletproof vests because of its high tensile strength-to-weight ratio.

Part of the structure of the polymer Kevlar is shown below.



Kevlar

(i) Draw the monomer(s) involved in the formation of Kevlar.

[2]

(ii) State the functional group present in Kevlar and state whether Kevlar is an addition or condensation polymer.

……[2]

(iii) Explain the high tensile strength of Kevlar in terms of its structure and bonding.

……

……[1]

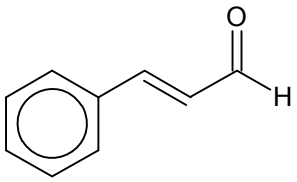
(iv) Explain why a bullet proof vest made of Kevlar should be stored away from concentrated acids.

……

……[1]

(b) The benzene ring is an important functional group for many naturally occurring aromatic compounds. The term 'aromatic' was used to describe a group of compounds, many of which have aromas.

The compound that gives cinnamon its characteristic smell is cinnamaldehyde



cinnamaldehyde

Draw the organic product obtained when cinnamaldehyde is treated with the following reagents. For each reagent, state the type of reaction that has occurred and record any observations.

I. $LiAlH_4$ in dry ether

Type of reaction and / or observations: ……

……

II. $K_2Cr_2O_7(aq)$, $H_2SO_4(aq)$, heat

Type of reaction and / or observations: ……

……[5]

[Total: 11]

End of Section A

Section B

Answer any <u>one</u> of the two questions.

For Examiners' Use

1 (a) Geckos are a type of reptiles that possess the ability to adhere to almost any surface. As such, research is undergoing to develop synthetic material that resembles the feet of geckos. The main reason why geckos can adhere to any surfaces is due to the nanostructures found on their feet.

(i) State what is the nanostructure found on geckos' feet.

……[1]

(ii) Explain how these nanostructures help geckos to stick to most surfaces.

……

……

……

……

……[3]

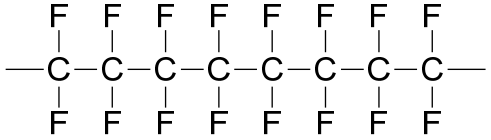
(b) One type of materials that some geckos are unable to adhere to is polytetrafluoroethylene (PTFE). PTFE is used in making non-stick pans and other cookwares.

(i) Define *polymers*.

……

……[1]

(ii) The structure of PTFE is given below.



Draw the repeat unit that make up PTFE.

[1]

For Examiners' Use

(iii) Thermoplastic and thermosetting polymers differ in their structure and bonding. Explain the differences in the rigidity and strength of thermoplastic and thermosetting polymers.

……

……

……

……

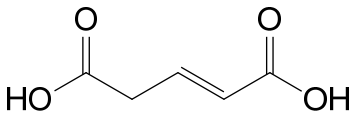
……

……[3]

(iv) Hence or otherwise, suggest if PTFE is a thermoplastic or thermosetting polymer.

……[1]

(c) Glutaconic acid is a product of hydrolysis of proteins in the human body. Excessive levels of glutaconic acid can lead to brain damage.

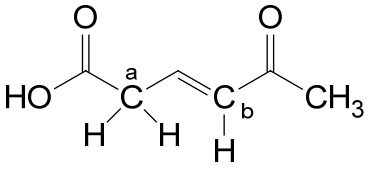


Glutaconic acid

(i) State the IUPAC name for glutaconic acid.

……[1]

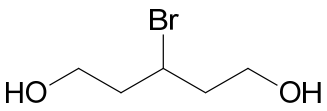
(ii) State the bond angle and shape around the carbon labelled as C_a and C_b.



C_a: ……

C_b: …… [2]

(iii) Draw the synthetic route and suggest reagents and conditions for each step to show how glutaconic acid can be synthesised from 3-bromopenta-1,5-diol. You are required to draw the structures of all intermediates.



3-bromopenta-1,5-diol

[3]

(iv) Describe a distinguishing test between glutaconic acid and 3-bromopenta-1,5-diol. State the observations, if any.

……

……[2]

(v) Glutaconic acid is soluble in water. Explain, in terms of structure and bonding, why this happens.

……

……[2]

[Total: 20]

For Examiners' Use

2 (a) Transition metals are very useful in the chemical industries as they can act as catalysts. Vanadium, iron and chromium are commonly used as catalysts for various common reactions.

(i) Write the electronic configuration of the following particles.

V^{6+}: ……

Cr^{6+}:……...[2]

(ii) Draw the shapes of the orbitals in which the valence electrons of V^{6+} occupy.

[2]

(iii) Define the sixth ionisation energy of vanadium.

…….....

…….....[1]

(iv) State whether the 6th ionisation energy of vanadium is higher or lower than that of chromium. Explain your answer.

…….....

…….....

…….....

…….....[3]

(v) Niobium (Nb) and tantalum (Ta) are elements below that of vanadium in the periodic table. State and explain the trend in atomic radii among the three elements.

…….....

…….....

…….....[2]

For Examiners' Use

(b) Haber process is a very important industrial process as it is the main process involved in making of fertilisers. A similar industrial process is the Contact process, which is the process of making sulfuric acid from sulfur. The main reaction is given below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197 \text{ kJ mol}^{-1}$$

(i) State what is meant by Le Chatelier's Principle.

……

……[1]

(ii) The reaction is carried out at 450 °C and 1.5 atm. Suggest, using Le Chatelier's Principle, why this may not be the ideal condition.

……

……[2]

(iii) An equilibrium was established at 700 °C in a 10 dm^3 vessel. The equilibrium amounts of sulfur dioxide, oxygen and sulfur trioxide were 10.0 mol, 4.0 mol and 25.1 mol.

Calculate K_c and state its units.

[3]

(iv) State the effect on the K_c calculated in **(b)(iii)** if the contact process is carried out at 450 °C instead of 700 °C.

……[1]

(c) **(i)** Many of the food consumed commonly contain acids. One of them is citric acid, found in citrus fruits. The dissociation of citric acid is given below.

$$H_3C_6H_5O_7\,(aq) + H_2O\,(l) \rightleftharpoons H_2C_6H_5O_7^-\,(aq) + H_3O^+\,(aq)$$

Write the K_a expression for the dissociation of citric acid.

……[1]

(ii) A sample of citric acid with the concentration of 0.01 mol dm^{-3} was obtained. The pH of the solution was measured and found to be 2.54. Calculate the concentration of H_3O^+ ions present in the solution.

[1]

(iii) Hence, deduce if citric acid is a strong or weak acid. Explain your answer.

…….....

…….....[1]

[Total: 20]

End of Section B

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