Class	Adm No

Candidate Name: _____

H

millennia institute

2018 End-of-Year Exams
Pre-University 2

H1 CHEMISTRY **8873/01**

Paper 1 Multiple Choice **13 Sept 2018**

1 hour

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

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

Write in soft pencil.

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

Write your name, class and admission number in the spaces provided at the top of this page and on the Multiple Choice Answer Sheet provided.

There are thirty questions on this paper. Answer **ALL** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

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Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this question paper.

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

FOR EXAMINER'S USE	
TOTAL (30 marks)	

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 According to the equation below, how many moles of potassium chlorate, $KClO_3$, must be decomposed to generate 1000 cm^3 of O_2 gas at standard temperature and pressure?

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

A $\frac{2}{3}\left(\frac{1}{24}\right)$ mol

B $\frac{3}{2}\left(\frac{1}{24}\right)$ mol

C $\frac{2}{3}\left(\frac{1}{22.7}\right)$ mol

D $\frac{3}{2}\left(\frac{1}{22.7}\right)$ mol

2 *Use of the Data Booklet is relevant to this question.*

It is suggested that SO_2 which contributes to acid rain, could be removed from a stream of waste gases by bubbling the gases through 0.25 mol dm^{-3} KOH, thereby producing K_2SO_3. What is the maximum mass of SO_2 that could be removed by 1000 dm^3 of the KOH solution?

A 4.0 kg

B 8.0 kg

C 16.0 kg

D 20.0 kg

3 To determine the molar mass of a weak monoprotic acid, a student titrated 25.0 cm^3 of the acid with aqueous NaOH. Which of the following are appropriate indicators that could be used for the titration?

1 Phenolphthalein
2 Methyl Orange
3 Bromothymol blue

A 1 only
B 1 and 2 only
C 2 and 3 only
D 1, 2 and 3

4 A sample of 30.0 cm^3 of 0.050 mol dm^{-3} iron(II) sulfate is titrated against 0.025 mol dm^{-3} potassium manganate(VII) solution. It is found that 20.0 cm^3 of the manganate(VII) solution is required to reach end point.
What is the oxidation number of manganese at the end point?

A +2
B +3
C +4
D +5

5 The number of orbitals of a principal quantum number is dependent on the type of subshell. Which of the following statements about the s, p and d orbitals of principal quantum numbers 1, 2 and 3 are true?

1 Each s orbital can hold a minimum of two electrons.
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A 3 only
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6 In the equilibrium represented below, which of the following species act as bases?

$$HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{2-}$$

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2 H_2O
3 SO_4^{2-}

A 3 only
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C 2 and 3 only
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7 Which of the following can be classified as a Lewis acid?

A An ion which accepts a pair of electrons to form a bond.
B A molecule which donates a pair of electrons to form a bond.
C A ion which accepts a proton from water.
D A molecule which donates a proton to water.

8 Which of the following is a non-polar molecule that contains polar bonds?

A F_2
B CHF_3
C CO_2
D NH_3

9 Which of the following species has a see-saw structure?

A BrF_4^+
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10 The energy profile diagram for the reaction X + Y → Z is shown below.

Which of the indicated energy differences is affected by the addition of a catalyst?

A I only
B II only
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Standard enthalpy change of formation of $NaHCO_3(s)$ / kJ mol^{-1}	-951
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Standard enthalpy change of formation of $CO_2(g)$ / kJ mol^{-1}	-394

What is the standard enthalpy change for the calcination reaction?

A +860 kJ mol^{-1} **B** +91 kJ mol^{-1} **C** -91 kJ mol^{-1} **D** -860 kJ mol^{-1}

12 Which of the following is associated with a relatively slow rate of a chemical reaction?

A high temperature
B low activation energy
C strong bonds in reactant molecules
D high concentration of reactants

13 The radioactive decay of a sample of ^{131}I follows a first order kinetics. If a pure sample of ^{131}I undergoes radioactive decay and the half-life of the decay was found to be 10 days, what would be the half-life of the decay in a separate experiment where the initial concentration of the pure sample of ^{131}I was doubled?

A 2.5 days
B 5 days
C 10 days
D 20 days

14 The following table shows the results from a rate study of the reaction **X** + **Y** → **Z**.

Experiment	[X] / mol dm^{-3}	[Y] / mol dm^{-3}	Initial rate of formation of Z / mol dm^{-3} s^{-1}
1	0.40	0.10	R
2	0.20	0.20	?

Starting with known concentrations of **X** and **Y** in experiment **1**, the rate of formation of **Z** was measured. If the reaction was first order with respect to **X** and second order with respect to **Y**, what is the initial rate of formation of **Z** in experiment **2**?

A $\frac{R}{4}$

B $\frac{R}{2}$

C R

D 2R

15 Equal amounts of HC*l* and O_2 in a closed system are allowed to reach equilibrium as represented by the equation below. Which of the following must be true at equilibrium?

$$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$$

1 [HC*l*] must be less than [Cl_2]

2 [O_2] must be greater than [HC*l*]

3 [Cl_2] must equal [H_2O]

A 3 only

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D 1,2 and 3

16 Carbon dioxide dissolves in water sparingly to produce carbonic acid, H_2CO_3.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

Carbonic acid further dissociates in water according to the two equations below.

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$$

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq)$$

How would the addition of a small amount of NaOH(aq) affect $[CO_2]$, $[HCO_3^-]$ and $[CO_3^{2-}]$ when carbon dioxide dissolves in water?

	$[CO_2]$	**$[HCO_3^-]$**	**$[CO_3^{2-}]$**
A	decrease	decrease	increase
B	decrease	negligible change	increase
C	decrease	Increase	increase
D	increase	negligible change	decrease

17 Which of the following statements concerning the characteristics of halogens is **incorrect**?

A The fourth ionisation energies decrease as the atomic numbers of the halogens increase.

B Fluorine is the strongest oxidising agent.

C The ease of decomposition of hydrogen halides decreases down Group 17.

D The acid strength of an aqueous solution of the hydrogen halides increases from HC*l* to HI.

18 Which of the following elements from Period 3 (sodium to chlorine) in the Periodic Table forms an oxide which dissolves in water to form a solution of pH 13?

A Sodium

B Silicon

C Sulfur

D Chlorine

19 $[Al(H_2O)_6]^{3+}$ ion is hydrolysed in aqueous solution according to the equation below.

$$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H_3O^+(aq)$$

Which statements about this reaction are true?

1 $[Al(H_2O)_5(OH)]^{2+}$ is relatively less likely to undergo hydrolysis compared to $[Al(H_2O)_6]^{3+}$.
2 The aluminium undergoes a change in oxidation state from +3 to +2.
3 The hydrolysis is favoured by low pH.

A 1 only
B 1 and 2 only
C 2 and 3 only
D 1,2 and 3

20 **G**, **H** and **J** are three elements found in Period 3 of the Periodic Table.

Among the elements in Period 3,

- The melting point of **G** is the highest.
- The electrical conductivity of **H** is the highest.
- The melting point of the oxides of **J** is the highest.

Which of the following elements is **not** represented by **G**, **H** or **J**?

A Na
B Mg
C A*l*
D Si

21 Based on the concepts of polarity and hydrogen bonding, which of the following sequences correctly lists the compounds below in the order of **increasing** solubility in water?

CH_3-CH_2-CH_2-CH_2-CH_3	CH_3-CH_2-CH_2-CH_2-OH	HO-CH_2-CH_2-CH_2-OH
X	**Y**	**Z**

A **Z < Y < X**

B **Y < Z < X**

C **Y < X < Z**

D **X < Y < Z**

22 Which of the following is true when one mole of ethane is mixed in the dark at room temperature with six moles of chlorine gas?

A CCl_3CCl_3 and HCl are formed.

B CH_3CH_2Cl and HCl are formed.

C CH_3CCl_3 and HCl are formed.

D There is no reaction.

23 An amine is prepared in the following reaction.

$$C_2H_5I + 2NH_3 \rightarrow C_2H_5NH_2 + NH_4I$$

What is the type of reaction taking place?

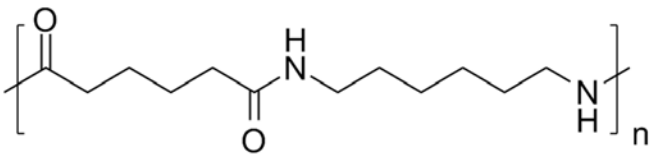
A addition

B substitution

C elimination

D redox

24 A repeat unit of nylon is shown below.



Nylon

Which of the following statements about nylon is correct?

A The monomers used are carboxylic acids and alcohols.
B It is formed via addition polymerisation.
C Water molecules are eliminated in the process of polymerisation.
D Hydrogen chloride molecules are eliminated in the process of polymerisation.

25 The mould *Phytophthora* damages many plants, destroying agricultural crops such as potatoes. A hormone-like compound called alpha 1 regulates the reproduction of all species of *Phytophthora*. The structure of alpha 1 is now known, giving scientists a key to the possible future eradication of the mould.

Which reagents will react with alpha 1?

1 $Br_2(aq)$
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A 1 only
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26 Which one of the following compounds will react with its own oxidation product to give a fruity smelling liquid?

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27 Which of the following has hydrogen bonds between its polymer chains?

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28 Which option best defines the size of nanoparticles?

A between 100 to 1000 nm
B between 0.1 to 10 nm
C between 1 to 100 nm
D between 0.01 to 1 nm

29 Carbon nanotubes usually form in bundles.

Which of the statements best describes the bundle seen it the figure above?

A The tubes are connected together by covalent C-C bonds.

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C The tubes are aligned, axes parallel, with dispersion forces operating between adjacent tubes.

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30 Which of the following pair of compounds show one compound which can be oxidised by acidified potassium dichromate(VI) and the other be reduced by sodium borohydride, $NaBH_4$?

$C_3H_7CH(OH)C_3H_7$	C_6H_5CHO	$C_3H_7COC_3H_7$	$(C_3H_7)_3COH$
I	**II**	**III**	**IV**

	Can be oxidised	**Can be reduced**
A	**I**	**II**
B	**II**	**IV**
C	**III**	**I**
D	**IV**	**III**

END OF PAPER 1

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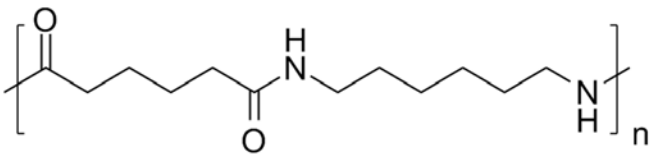

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D Hydrogen chloride molecules are eliminated in the process of polymerisation.

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A between 100 to 1000 nm
B between 0.1 to 10 nm
C between 1 to 100 nm
D between 0.01 to 1 nm

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Which of the statements best describes the bundle seen in the figure above?

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I	**II**	**III**	**IV**

	Can be oxidised	Can be reduced
A	**I**	**II**
B	**II**	**IV**
C	**III**	**I**
D	**IV**	**III**

END OF PAPER 1

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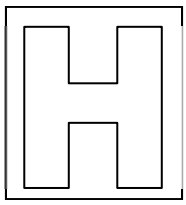
Class | Adm No

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

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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]

For Examiners' Use

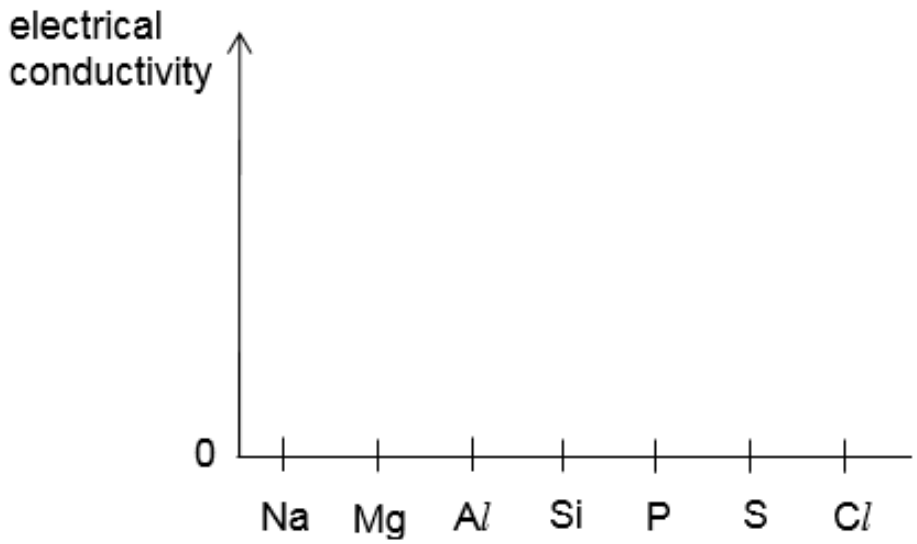
(d) Unlike $MgCl_2$, $AlCl_3$ has the tendency to dimerise to form Al_2Cl_6.
Draw the 'dot-and-cross' diagram of Al_2Cl_6 and explain how the dimer was formed.

……

……

……[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]

For Examiners' Use

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)**.

……

……

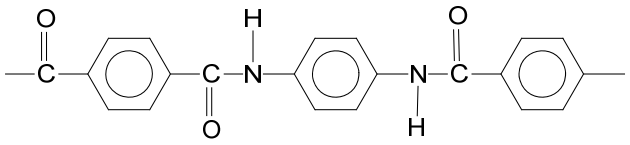
……

……[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]

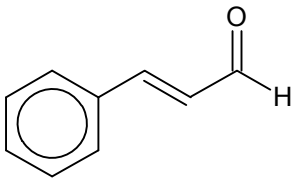
(iv) Explain why a bullet proof vest made of Kevlar should be stored away from concentrated acids.

……

……[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]

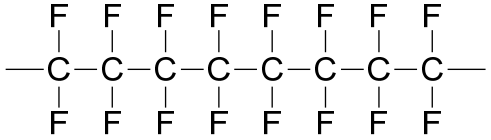
(b) One type of materials that some geckos are unable to adhere to is polytetrafluoroethylene (PTFE). PTFE is used in making non-stick pans and other cookwares.

(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.

……

……

……

……

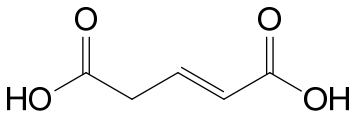
……

……[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.

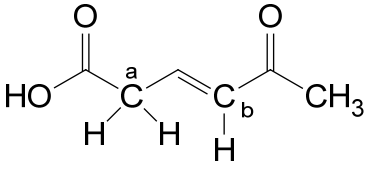


Glutaconic acid

(i) State the IUPAC name for glutaconic acid.

……[1]

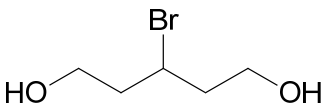
(ii) State the bond angle and shape around the carbon labelled as C_a and C_b.



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]

(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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Class | Adm No

Candidate Name: _____

H

millennia institute

2018 End-of-Year Exams
Pre-University 2

H1 CHEMISTRY **8873 / 02**

Paper 2 Structured Questions **11 Sep 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]

Comparing Expt 1 & 2,

when $[Br^-]$ increases by 2 times, rate increases by 2 times $(\frac{8x10^{-2}}{4x10^{-2}})$. [1]

⇒ rate is directly proportional to $[Br^-]$

⇒ reaction is 1st order with respect to Br^- [1]

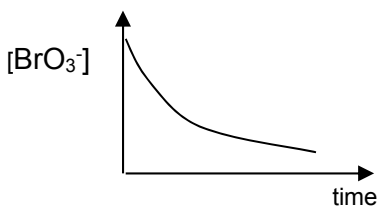
Comparing Expt 2 & 3,

when $[BrO_3^-]$ increases by 2 times, rate increases by 2 times $(\frac{4x10^{-2}}{2x10^{-2}})$.

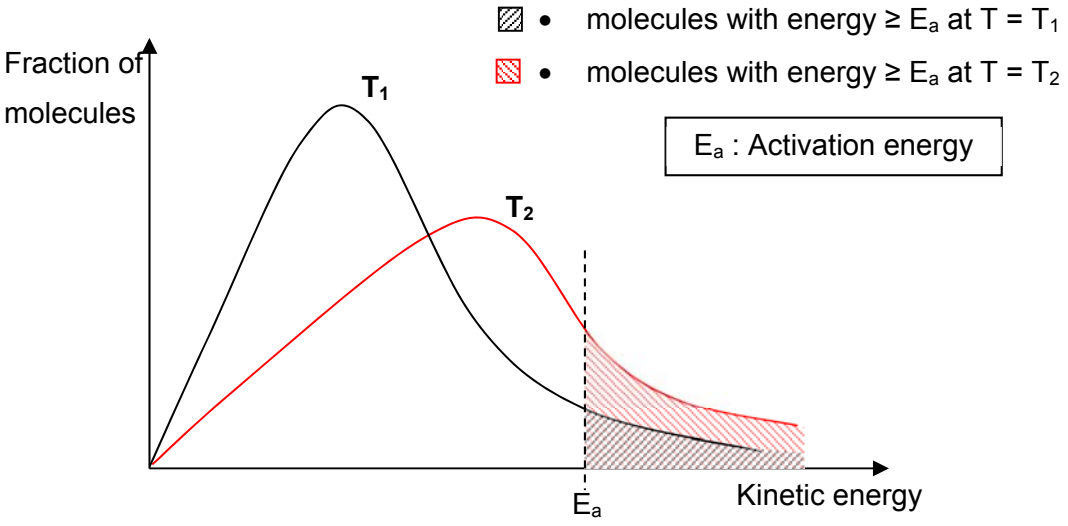
⇒ rate is directly proportional to $[BrO_3^-]$

⇒ reaction is 1st order with respect to BrO_3^- [1]

(ii) Based on your answer in **(a)(i)**, sketch a concentration-time graph for BrO_3^-. [1]



(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]



When temperature increases, the average kinetic energies of the reactant molecules increase.
Thus, the number of reactant molecules with energy greater or equal to the activation energy will increase. This results in an increase in the frequency of effective collisions.
Hence, the rate of reaction increases.

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

I. BrO_3^-,

II. bromide,

III. bromine [3]

+5, -1, 0

(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]

Amount of BrO_3^- = 20/1000 x 0.0200 = 0.0004 mol

Amounf of NH_2OH = 80/1000 x 0.01 = 0.0008 mol ;

Amount of e gained by BrO_3^- = 0.0004 x 6 = 0.0024 mol ;

Mole ratio of NH_2OH: electrons = 0.0008:0.0024 = 1:3 ;

Final oxidation number of N = -1 – (-3) = +2 ;

(iii) Based on your answer in **(b)(ii)**, suggest a possible product for the oxidation of hydroxylamine. [1]

NO
(ecf based on (b)(ii))

[Total: 15]

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

(a) State and explain **two** factors that leads to aluminium having a higher melting point than magnesium. [2]

From Mg to Al, the number of delocalised electrons and charge density of metal cation increases, thus the strength of metallic bond also increases from. Hence there is an increase in melting point from Mg to Al

(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]

The melting point of Al_2O_3 is lower than MgO due to Al_2O_3 being an ionic compound with partial covalent character. This occurs as the Al^{3+} cation has a high charge density and can strongly polarise/distort the electron cloud of the O^{2-} anion.

(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

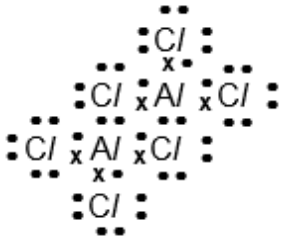
II. Al_2O_3 did not dissolve when added to water. [2]

$MgO\ (s) + H_2O\ (l) \rightleftharpoons Mg(OH)_2\ (aq)$

Al_2O_3 has high lattice energy.

(d) Unlike $MgCl_2$, $AlCl_3$ has the tendency to dimerise to form Al_2Cl_6.

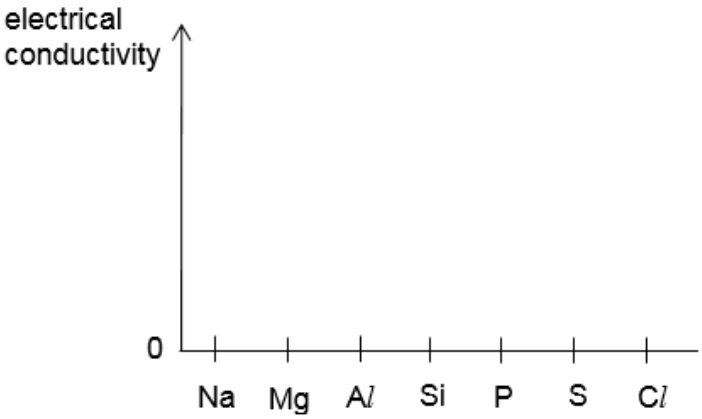
Draw the 'dot-and-cross' diagram of Al_2Cl_6 and explain how the dimer was formed. [3]

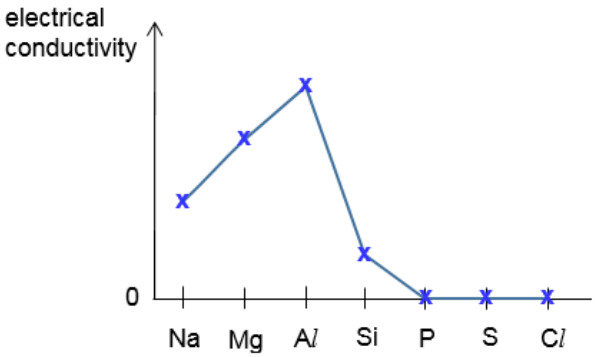


Chlorine atom possess a lone pair of electrons in its valence quantum shell.

Aluminium has energetically-accessible vacant orbitals in its valence quantum shell to accommodate the lone pair of electrons from chlorine to form a dative covalent bond.

(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]

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Mazda Motor Corporation has unveiled a new generation of catalytic converters that use 70% to 90% less of the precious metals which help 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]

$2CO + O_2 \rightarrow 2CO_2$

(ii) Suggest why automotive catalysts use nanoparticles instead of larger particles. [2]

The higher surface area to volume ratio of platinum nanoparticles increases catalytic efficiency in catalytic converters. There are more collisions between the reactants and catalyst, increasing the frequency of effective collisions, thus speeding up the chemical reactions.

(iii) Explain why having platinum and palladium in catalysts can translate into health risks.[1]

The small size of nanoparticles means that nanoparticles can be easily inhaled and absorbed by the lungs and subsequently absorbed into the blood steam. This can lead to health risks such as asthma, poisoning of the blood.

(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 points 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]

Both CO and NO are simple covalent molecules. Both CO and NO has pd-pd forces of attraction between its molecules. However, NO has a larger size of electron cloud, thus more thermal energy is required to overcome the stronger pd-pd forces of attraction in NO, thus NO has a higher boiling point and a longer retention time.

(ii) Draw a dot-and-cross diagram to illustrate the bonding in CO_2.

State its shape and bond angle. [2]

O==C=O, linear, 180^o

(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]

Alkene

(ii) Identify the number of sigma and pi bonds in compound **A**. [2]

14 sigma, 1 pi

(iii) Draw **and** name any **three** possible structures of **A**. [3]

Pent-2-ene / pentene / 3-methyl butene

(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]

CH_3COCH_3

[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)** Explain the term *bond energy*. [1]

The energy required to break one mole of a covalent bond between two atoms of a molecule in gaseous state, under standard conditions of 298 K, 1 bar.

(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]

The C-C bond in the butane consists of 1 sigma bond. The C=C in but-1-ene consists of 1 sigma and 1 pi bond.

A pi bond is weaker than a sigma bond due to less effective overlap, hence C=C bond is less than twice of C-C bond.

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

$CH_3CH_2CH=CH_2 + 6O_2 \rightarrow 4CO_2\,(g) + 4H_2O$

(ii) Hence, use the bond energies in the *Data Booklet* to calculate the standard enthalpy change of combustion of gaseous but-1-ene. [3]

$\Delta H = [2\times BE(C\text{-}C) + BE(C=C) + 8\times BE(C\text{-}H) + 6\times BE(O=O)] - [8\times BE(C=O) + 8\times BE(O\text{-}H)]$
$= (2\times 350 + 610 + 8\times 410 + 6\times 496) - (8\times 740 + 8\times 460)$
$= 7566 - 9600$
$= -2034 \approx -2030 \text{ kJ mol}^{-1}$

(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]

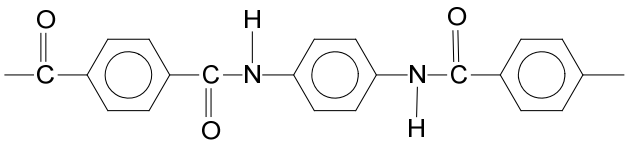
The magnitude will be larger.

When water condenses into liquid, addition energy is released.

[Total: 9]

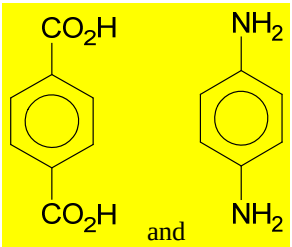
5 Kevlar is a heat-resistant and strong synthetic fibre used in many applications from bicycle tyres to bulletproof vests because of its high tensile strength-to-weight ratio.

(a) **(i)** Part of the structure of the polymer Kevlar is shown below.



Kevlar

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]

Amide

Condensation polymer.

(iii) Explain the high tensile strength of Kevlar in terms of its structure and bonding. [1]

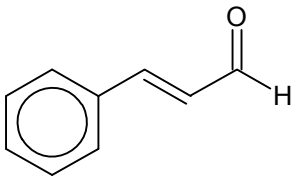
When the polymer chains are aligned, the molecules are held together by strong hydrogen bonds. / id-id

(iv) Explain why a bullet-proof vest made of Kevlar should be stored away from concentrated acids. [1]

In the presence of acids, the amide linkages holding the monomers can be hydrolysed, thus disrupting the structure of Kevlar.

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

The compound that gives cinnamon its characteristic smell is cinnamaldehyde

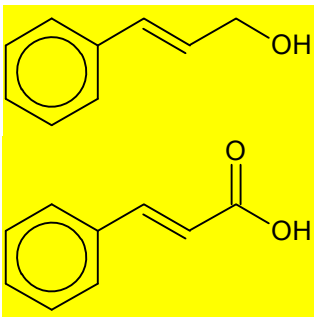


cinnamaldehyde

Draw the organic product obtained when cinnamaldehyde is treated with the following reagents:

I. $LiAlH_4$ in dry ether
II. $K_2Cr_2O_7(aq)$, $H_2SO_4(aq)$, heat

For each reagent, state the type of reaction that has occurred and record any observations observed. [5]



reduction

oxidation; $K_2Cr_2O_7$ solution changed from orange to green.

[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]

Spatulae

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

[3]

Spatulae forms instantaneous-dipole induced-dipole interactions with the surface. As the spatulae have high surface area to volume ratio, there is a huge cumulative surface area of contact between the gecko's feet and the surface. As such, there is a strong collective adhesive force that allows the gecko to stick on the surface.

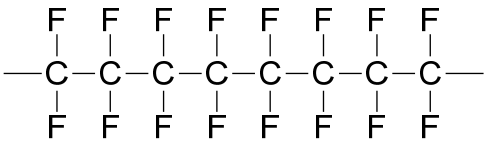
(b) One type of materials that some geckos are unable to adhere to is polytetrafluoroethylene (PTFE). PTFE is used in making non-stick pans and other cookwares.

(i) Define *polymers*.

[1]

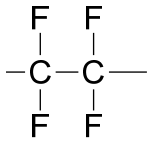
macromolecules built up from monomers, with average molar mass of at least 1000 or at least 100 repeat units.

(ii) The structure of PTFE is given below.



Draw the repeat unit that make up PTFE.

[1]



(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]

Thermoplastics are made of linear polymers whereas thermosets are made of polymers with crosslinks.

The branches of LDPE prevent maximum surface area of contact between the polymeric molecules. As a result, the instantaneous dipole-induced dipole (i.d.-i.d.) between the molecules are not extensive, less energy is required to break the i.d.-i.d. between molecules, leading to lower melting point and also greater distance of separation between the molecules. The greater distance of separation results in lower density as the mass per unit volume is smaller. The lower tensile strength arises because of the weak i.d.-i.d. too.

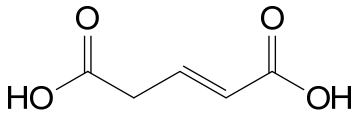
In general, branched-chain polymers would have a lower melting point, density and tensile strength than linear chain polymers of the same type.

(iv) Hence or otherwise, suggest if PTFE is a thermoplastic or thermosetting polymer. [1]

PTFE is a thermoplastic as it is a linear polymer.

For Examiners' Use

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



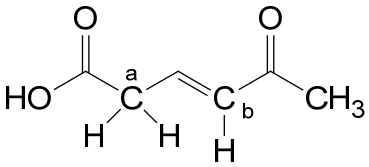
Glutaconic acid

(i) State the IUPAC name for glutaconic acid.

[1]

pent-2-ene-1,5-dioic acid / 2-pentene-1,5-dioic acid

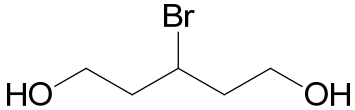
(ii) State the bond angle and shape of the carbon stated.



[2]

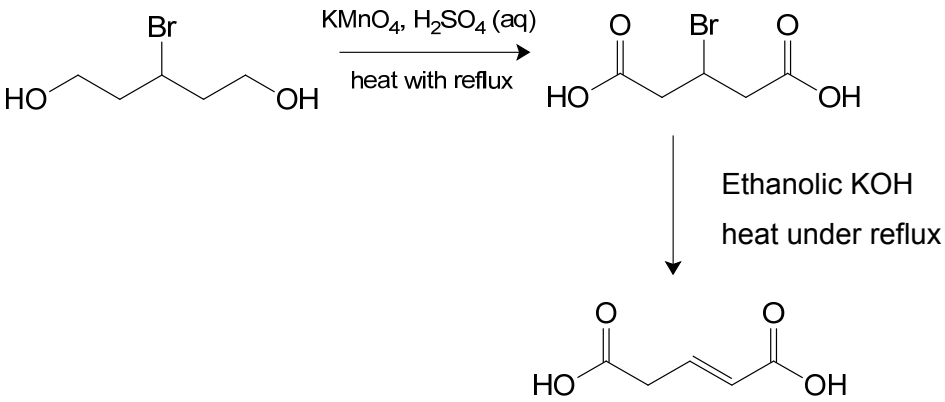
Cα: 109.5°, tetrahedral
Cβ: 120°, trigonal planar

(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]

Aqueous bromine. For 3-bromo-penta-1,5-diol, the orange aq. bromine will remain whereas for glutaconic acid orange aq bromine decolourises.

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

[2]

Glutaconic acid is a simple covalent molecule held together by hydrogen bonds. energy evolved from the formation of hydrogen bonds with water is sufficient enough to overcome the hydrogen bonds between the glutaconic acid molecules.

[Total: 20]

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

For Examiners' Use

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

V^{6+}: ……

Cr^{6+}: ……..

[2]

V^{6+}: $1s^2 2s^2 2p^6 3s^2 3p^5$

Cr^{6+}: $1s^2 2s^2 2p^6 3s^2 3p^6$

(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]

It will be higher for vanadium.

V^{5+}: $1s^2 2s^2 2p^6 3s^2 3p^6$

Cr^{5+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$

More energy is needed to remove the electron from the 3p orbital of V^{5+} as compared to the 3d orbital of Cr^{5+} as the 3p orbital is nearer to the nucleus and hence experiences weaker screening.

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

[2]

The atomic radii increase in this manner: V > Nb > Ta.

Down the group, the number of principle quantum shells increases, hence the distance between the valence electrons and nucleus increases. As such, strength of electrostatic attraction decreases and atomic radius decrease down the group.

(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]

Le Chatelier's Principle states that when a system in equilibrium is disturbed, the position of the equilibrium will shift in a direction that tends to reduce that change so as to re-establish the equilibrium.

(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]

The pressure is lower / close to the atmospheric pressure. If the pressure is higher, by LCP, the equilibrium position will shift towards the right so as to where there is lesser number of gaseous molecules which will help to improve the yield.

(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]

$$K_c = \frac{[SO_3]^2}{[O_2][SO_2]^2}$$

$$K_c = \frac{\left[\frac{25.1}{10}\right]^2}{\left[\frac{4.0}{10}\right]\left[\frac{10.0}{10}\right]^2} = \mathbf{15.8 \text{ mol}^{-1}\text{dm}^3}$$

(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]

K_c will increase

(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]

$$K_a = \frac{[H_3O^+][H_2C_6H_5O_7^-]}{[H_3C_6H_5O_7]}$$

(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]

$[H_3O^+] = 10^{-2.54} = 2.88 \times 10^{-3}$ mol dm^{-3}

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

[1]

Citric acid is a weak acid as $[H_3O^+]$ is smaller than that of [citric acid].

[Total: 20]

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