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DUNMAN HIGH SCHOOL

Preliminary Examinations 2017

Year 6

H1 CHEMISTRY

Paper 2 Section A (Structured)

Paper 2 Section B (Free Response)

8872/02

11 September 2017

2 hours

Additional Materials: Data Booklet
Writing Paper
Cover Sheet

INSTRUCTIONS TO CANDIDATES

- 1 Answer **ALL** questions in both sections.
- 2 Write your **name**, **index number** and **class** on this cover page.

Section A

- 3 Write your answers in the spaces provided on this question paper.

Section B

- 4 Write your **name**, **index number** and **class** on the Cover Sheet provided.
- 5 Write your answers on the separate writing papers provided.
- 6 **Start each question on a fresh sheet of paper.**
- 7 At the end of the examination:
 - Fasten all your work securely together with the Cover Sheet on top.

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

You are advised to show all workings in calculations.

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use	
Question No.	Section A Marks
1	13
2	14
3	13
Total	40

Section A

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

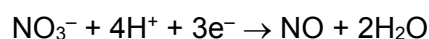
- 1 (a) Vanadium is a metal with four possible stable oxidation states in aqueous solutions.

Vanadium-containing species	Oxidation state of vanadium	Colour of aqueous solution containing species
VO_2^+	+5	Yellow
VO^{2+}	+4	Blue
V^{3+}	+3	Green
V^{2+}	+2	Violet

A solution of VO_2^+ can be easily reduced by metals like zinc and tin. Depending on the reducing strength of the metal, VO_2^+ would be reduced to different products.

A 250 cm^3 solution containing $0.60 \text{ mol dm}^{-3} \text{VO}_2^+(\text{aq})$ was reduced to $\text{V}^{2+}(\text{aq})$ by an excess amount of zinc. After filtration to remove the excess zinc, 25.0 cm^3 of the filtrate containing $\text{V}^{2+}(\text{aq})$ was pipetted into the conical flask and titrated against 1.0 mol dm^{-3} nitric acid, which acted as an oxidising agent, until there was no further change in the colour of the solution.

The half-equation for the reduction of nitric acid is



The titre values were as recorded.

Final burette reading / cm^3	11.00	21.05	31.45
Initial burette reading / cm^3	0.00	11.00	21.50
Volume of HNO_3 / cm^3	11.00	10.05	9.95

- (i) By using appropriate titre values, calculate the average titre value for the titration.

[1]

- (ii) Determine the reacting mole ratio of V^{2+} and NO_3^- .

[2]

- (iii) Hence, determine the oxidation state of vanadium after titration and the colour of the vanadium-containing solution, using the table in (a).

[2]

- (iv) Using your answer in (iii), construct a balanced equation for the reaction between $V^{2+}(aq)$ and nitric acid.

[1]

- (b) Describe the bonding in the element vanadium. Draw a diagram to illustrate your answer.

[2]

- (c) (i) Write the full electronic configuration of vanadium in VO^{2+} .

[1]

- (ii) Draw labelled diagrams of two p orbitals from different quantum shells of the element vanadium, illustrating their shapes and sizes.

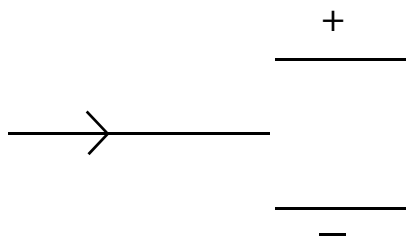
[1]

- (iii) Beams consisting of the particles, $^{16}\text{O}^{2-}$ and $^{51}\text{V}^{2+}$, are subjected to an electric field. The angle of deflection of the particles is proportional to their charge/mass ratio.

Given that the angle of deflection of $^{51}\text{V}^{2+}$ in the electric field is $+5^\circ$, suggest the angle of deflection of $^{16}\text{O}^{2-}$ in the electric field.

[1]

- (iv) Using your answer in (iii), sketch and label on the diagram below to show how beams of each of the two particles are affected by the electric field.



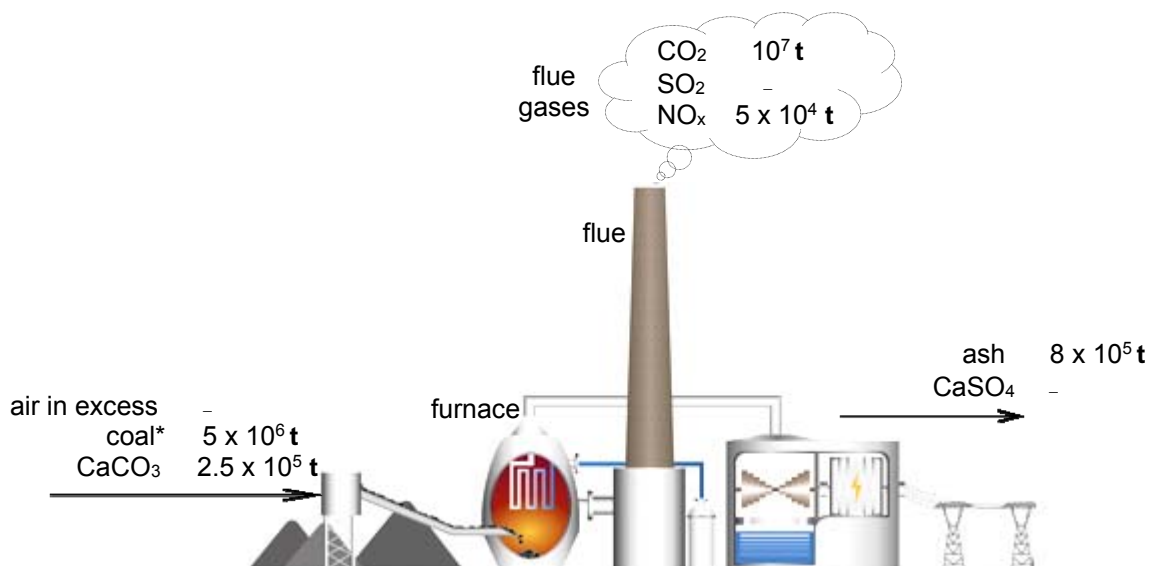
[2]

[Total: 13]

- 2 A coal-fired power station (which generates electricity) is fitted with a Flue Gas Desulfurisation (FGD) plant, which removes some of the sulfur dioxide from flue (waste) gases.

In the FGD plant, the flue gases are treated with powdered limestone, CaCO_3 , where sulfur dioxide is absorbed and reacted to produce calcium sulfite, CaSO_3 . This is oxidised by air to form solid calcium sulfate, CaSO_4 .

The diagram below shows the amounts of substances used, and produced, by such a coal-fired power station with an FGD plant in **one** year.



Power station & FGD plant

*coal is chiefly hydrocarbons

- (a) (i) State the process that produces the energy in the power station.

[1]

- (ii) Identify a gas, not listed in the diagram, which will be a chief component of the flue gas.

[1]

- (iii) Explain why oxides of nitrogen (NO_x) are present in the flue gases.

[1]

- (b) Write a balanced equation in each case to show how

- sulfur dioxide is removed from flue gases;

- calcium sulfate is formed.

.....
[2]

- (c) Using your answer in (b), determine the maximum mass of sulfur dioxide which could be removed in the FGD plant.
[1t = 1 tonne = 1000 kg]

[1]

- (d) Given that your answer in (c) was only 90% of the sulfur dioxide removed from the flue gases, calculate the mass of sulfur dioxide which is released into the atmosphere in **five** years by this power station when the same mass of coal is burnt each year.

[1]

- (e) Another method for removing sulfur dioxide from the flue gases is to absorb it in a slurry of magnesium oxide, to produce magnesium sulfite, MgSO_3 .

Explain why magnesium oxide can also be used to remove sulfur dioxide.

.....
[1]

- (f) Besides magnesium oxide, other metal oxides like sodium oxide and calcium oxide can also be used to remove sulfur dioxide.

The melting points of the three metal oxides are shown below.

oxides	m.p. / °C
MgO	2852
Na ₂ O	1132
CaO	2572

- (i) Given that the ionic radius of O²⁻ is 0.140 nm and with reference to *Data Booklet*, calculate $\left| \frac{q_+q_-}{r_+ + r_-} \right|$ for the metal oxides and complete the table below. (q_+ represents the charge of ion and r_+ represents its ionic radius)

oxides	$\left \frac{q_+q_-}{r_+ + r_-} \right $
MgO	
Na ₂ O	8.5
CaO	

[1]

- (ii) Using your answer in (i), explain the melting points of these oxides.

.....

.....

.....

.....

[1]

- (iii) For an ionic compound to dissolve in water, its ionic bonds have to be broken.

The pH of the resulting solutions when one mole of MgO and Na₂O are added to water separately are shown in the table below.

Predict and suggest an explanation for the pH value of CaO, with reference to your answer in (i).

oxides	pH of resulting solution
MgO	9
Na ₂ O	13
CaO	

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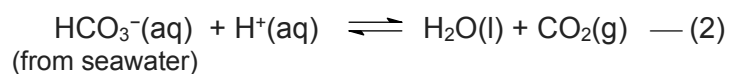
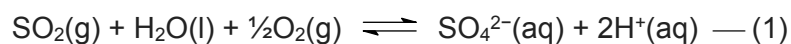
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[2]

- (g) Seawater is a natural reagent that can be used to absorb and remove SO₂. When SO₂ is absorbed in water, the following two equilibria reactions take place:



Explain how the use of seawater would allow the removal of sulfur dioxide.

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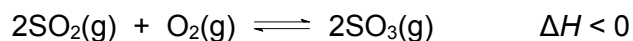
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[2]

[Total: 14]

- 3 Sulfuric acid is a strong mineral acid which is an important chemical used in industry and in the school laboratory. It is manufactured industrially by the Contact process.

The key reaction involves the reaction between sulfur dioxide and oxygen.



69.2 mol of sulfur dioxide is mixed with 34.6 mol of oxygen in a 2 dm³ vessel and passed over several beds of loosely packed porous vanadium catalyst. The amount of sulfur trioxide at equilibrium is found to be 65.6 mol.

- (a) (i) Calculate a value for the equilibrium constant, K_c , stating its units.

[2]

- (ii) Use your value of K_c to calculate the $[\text{O}_2]$ necessary for 99% of the SO_2 to be converted to SO_3 .

[2]

- (iii) Explain qualitatively why the rate of achieving equilibrium increases in the presence of vanadium catalyst.

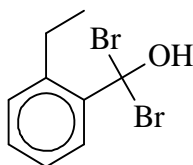
[2]

- (iv) Sketch a graph to show how the rates of the forward and reverse reactions change from the time the two gases are mixed to the time the reaction reaches equilibrium. Label your lines clearly.

[1]

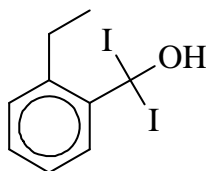
- (b) Sulfuric acid is commonly used to acidify a solution of potassium manganate (VII).

- (i) Draw the structure of the organic product formed when compound **W** is heated with acidified potassium manganate (VII).

compound **W**

[1]

- (ii) A derivative of compound **W** is shown below.



compound **X**

Describe a chemical test to distinguish samples containing compounds **W** and **X** and state what would be observed.

.....

.....

.....

.....

[2]

- (iii) When compound **W** is treated with chlorine under two different conditions, isomeric monochlorides are formed.

Two isomers are formed via condition 1 and four isomers are formed via condition 2.

Draw the structures of one isomer formed via condition 1 and condition 2 respectively and state the reagents and conditions required for condition 1.

Isomer formed via Condition 1

Isomer formed via Condition 2

Condition 1

Reagent:

Conditions:

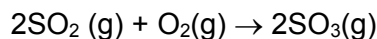
[3]

[Total: 13]

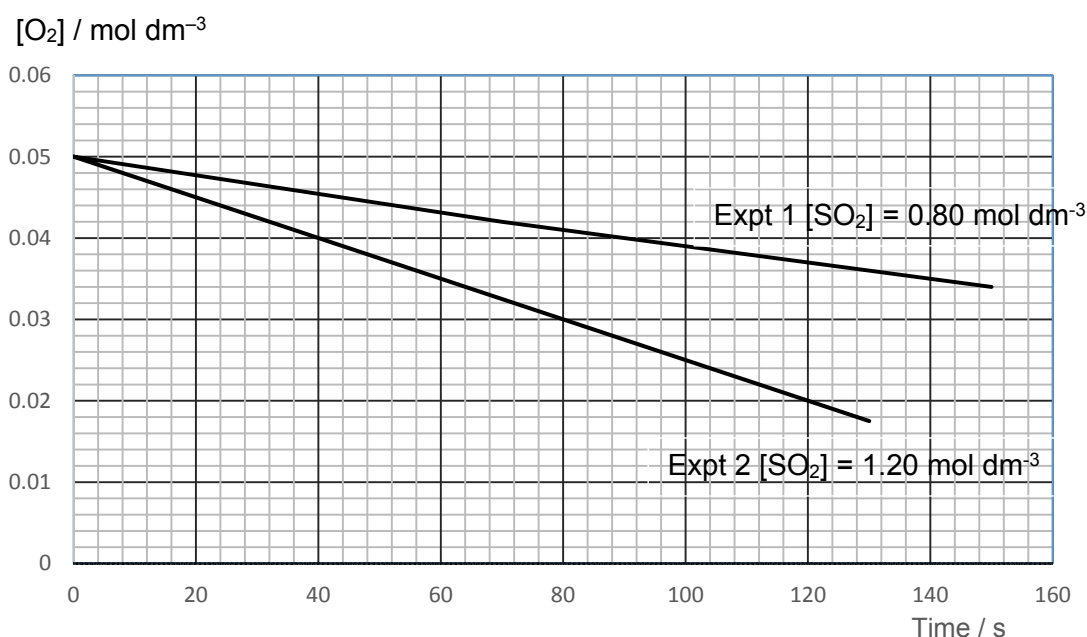
Section B

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

- 1 (a) The Contact Process is an industrial process for manufacturing sulfuric acid and occurs at 450 °C. The key stage in this process is the reaction between sulfur dioxide and oxygen.

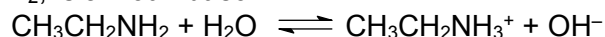


Two experiments were conducted at 450 °C to investigate the kinetics of this reaction. The graph below shows the results obtained when concentrations of sulfur dioxide were varied.



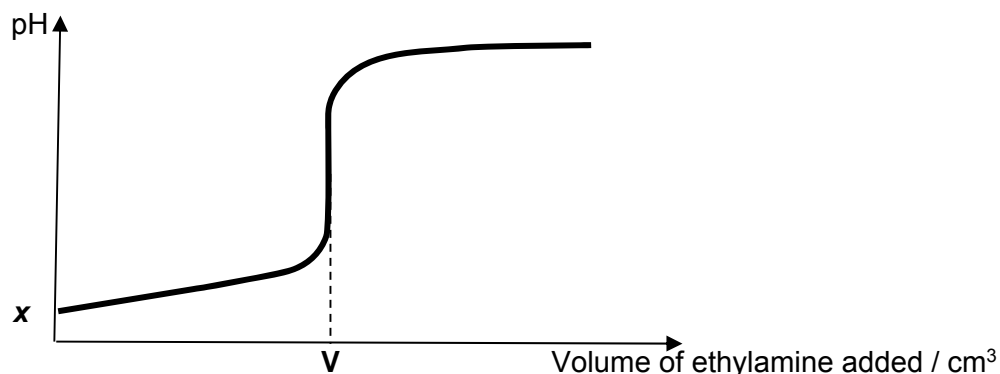
- (i) Define the term *order of reaction*. [1]
- (ii) Use the graph above to deduce the order of reaction with respect to both sulfur dioxide and oxygen. [3]
- (iii) Using one of the graph above and your answer in (ii), calculate the value of rate constant, stating its units. [2]
- (iv) Using your answer in (ii), sketch the graph of concentration of sulfur dioxide against time for this reaction, while keeping [O₂] constant. Use construction lines to label the first and second half-lives in your sketch. [1]
- (v) Sketch and label clearly, on the same axes as in (iv), how the graph would look like if the experiment was conducted at 200 °C. [1]

Ethylamine, CH₃CH₂NH₂, is a *weak base*.



- (b) What is meant by the term *weak base*? [1]
- (c) Write an expression for the base dissociation constant of ethylamine, K_b . [1]

- (d) The graph below shows the pH changes during the titration of 10.0 cm³ of 0.10 mol dm⁻³ sulfuric acid with 0.10 mol dm⁻³ ethylamine. During this titration, ethylamine is added gradually, from a burette, until a total volume of 30.00 cm³ has been added to the acid.



- (i) Calculate x , the initial pH of sulfuric acid before titration. [1]
- (ii) What is the equivalence volume of ethylamine, V , for the neutralisation of 10.0 cm³ of 0.10 mol dm⁻³ sulfuric acid? [2]
- (iii) An aqueous solution of ethylamine and its salt can act as a buffer. Copy the titration curve onto your answer script and label the buffer region. [1]
- (iv) Use the data in the following table to suggest a suitable indicator for the titration of sulfuric acid with ethylamine. Justify your answer.

State the colour change of your chosen indicator at the end-point of this titration.

indicator	colour in acid	colour in alkali	pH range over which the colour change occurs
Bromocresol green	yellow	blue	3.8 – 5.4
Cresol red	yellow	red	7.2 – 8.8
Alizarin yellow	yellow	orange	10.1 – 13.0

- (e) Concentrated sulfuric acid is a common reagent used in many organic reactions. When concentrated sulfuric acid is added to 3-hydroxypentanoic acid, one possible product formed is **A**, with the molecular formula C₅H₈O₂. **A** turns blue litmus paper red. **A** also gives effervescence when heated with acidified potassium manganate (VI) and only one organic product, **B**, is formed. [2]

Suggest the structural formula of **A** and **B**.

- (f) How would you expect the acidity of 3-hydroxypentanoic acid to compare with that of pentanoic acid? Explain your answer. [2]

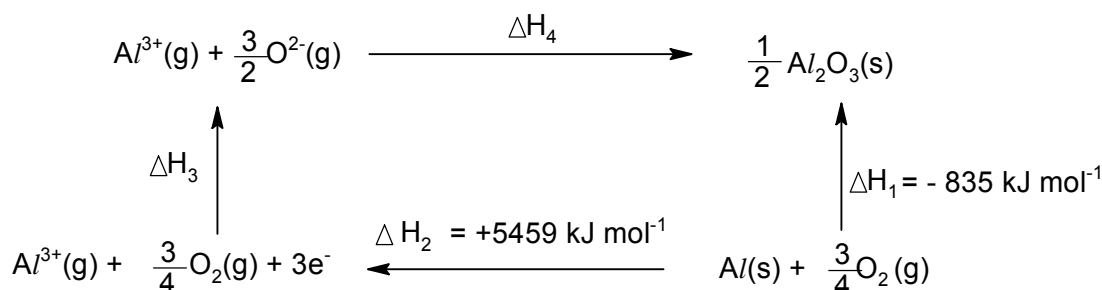
[Total: 20]

2 Below shows part of an edited abstract from a scientific journal.

'Two aluminium compounds, $AlCl_3$ and Al_2O_3 , were used to determine the effect of Al compounds on pH and bioavailability of Al in 2 acid soils. Al-tolerant (ET8) wheat seedlings were used as a testing plant to confirm bioavailability of Al^{3+} in soil solution. The results showed that the $AlCl_3$ compound increased the bioavailability of Al^{3+} in soil solutions and decreased bulk soil pH. However, Al_2O_3 did not change soil pH and the bioavailability of Al^{3+} in soil solution.'

Md. Toufiq IQBAL (2012), *Effect of Al compounds on soil pH and bioavailability of Al in two acid soils*, Turk J Agric, 720 – 728

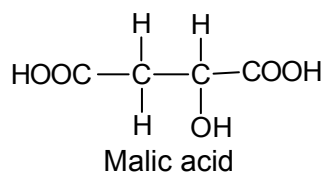
- (a) (i) Suggest why Al_2O_3 did not change the bioavailability of Al^{3+} in soil solution. [1]
 (ii) Explain how does $AlCl_3$ decrease soil pH in solution? Giving a balanced equation to support your answer. [3]
- (b) Consider the following energy cycle involving Al_2O_3 .



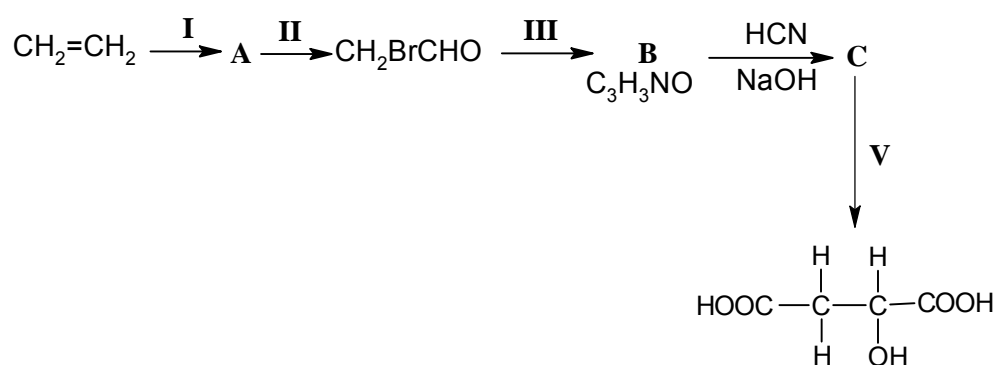
- (i) What enthalpy change does ΔH_1 represent? [1]
 (ii) Explain what is meant by the term *enthalpy change of formation*, ΔH_f , of $O^{2-}(g)$.
 Given that ΔH_f of $O^{2-}(g)$ is $+950 \text{ kJ mol}^{-1}$, calculate ΔH_3 . [2]
 (iii) Hence, use the above cycle and Hess' Law to calculate ΔH_4 . [1]
 (iv) Construct a reaction pathway diagram for the reaction below, showing clearly the activation energy and the enthalpy change of the reaction.
 $Al(s) + \frac{3}{4}O_2(g) \longrightarrow \frac{1}{2}Al_2O_3(s) \quad \Delta H_1 = -835 \text{ kJ mol}^{-1} \quad E_a = +126 \text{ kJ mol}^{-1}$ [2]
 (v) Calculate the activation energy of the reverse reaction. [1]

Most plant species tolerate the toxic effect of Al by forming stable complexes using an organic acid derivative, malate.

- (c) Malate is formed when malic acid reacts with excess aqueous NaOH. Draw the displayed formula of malate.



- (d) Malic acid can be formed from ethene. CH_2BrCHO is one of the intermediates as seen in the reaction scheme below. [2]

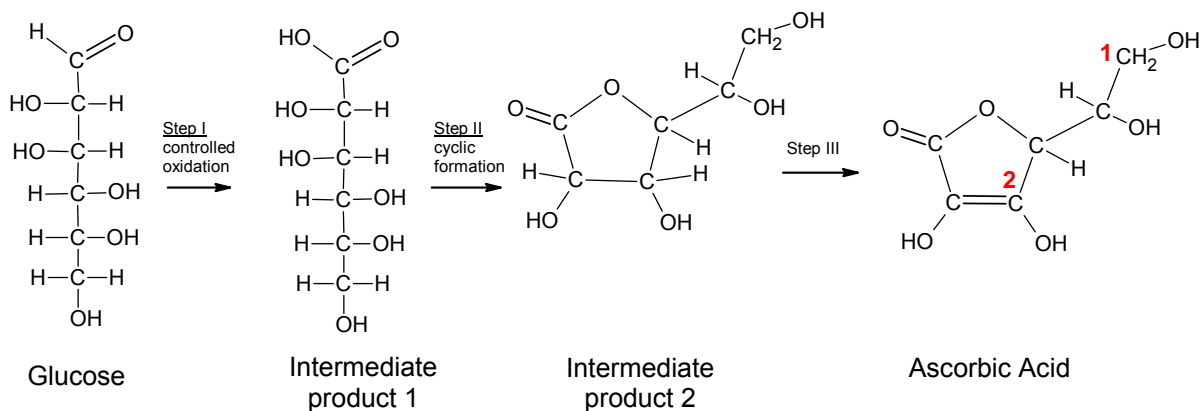


- (i) Suggest an identity for compound A, B and C. [3]
- (ii) Suggest reagents and conditions for reaction I, II, III and V. [4]

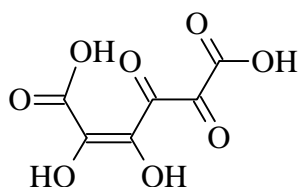
[Total: 20]

- 3 Ascorbic acid, better known as vitamin C, is a vitamin found in food and used as a dietary supplement. As a supplement, it is used to treat and prevent scurvy. It is known to be water soluble.

The building block for ascorbic acid is the glucose molecule. The proposed synthetic pathway is shown below.



- (a) (i) Name the functional groups present in intermediate product 2. [1]
- (ii) State the type of reaction found in **step II** and hence, copy *intermediate product 1* and **circle** the functional group(s) that is/are involved in the reaction. [2]
- (iii) With reference to structure and bonding, explain why ascorbic acid is soluble in water. [2]
- (iv) Predict, with reason, the relative solubility of ascorbic acid and glucose. [1]
- (v) The ascorbic acid molecule was heated with acidified potassium dichromate (VI) to form the compound shown below. [1]



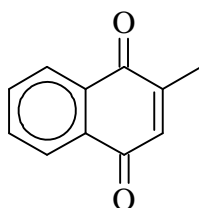
It was then reacted with hydrazine, $\text{H}_2\text{N}=\text{NH}_2$, which reacts in a similar way to 2,4-dinitrophenylhydrazine.

Draw the structural formula of the product formed upon reaction with hydrazine.

- (vi) Write a balanced equation for the reaction between one mole of intermediate product 1 and excess PCl_5 . [1]
- (vii) For each of C_1 and C_2 of ascorbic acid, state [1]
- I type of hybridisation
 - II shape
 - III no. of σ and π bonds

[3]

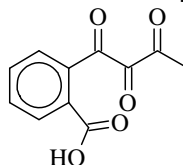
- (b) Vitamin C and K are both important nutrients with many health benefits. The structure of Vitamin K is shown below.



Vitamin K

Compound **A** ($C_{11}H_8O_2$) is a constitutional isomer of Vitamin K.

Compound **A** gives a yellow precipitate with alkaline aqueous iodine. When treated with



hot acidified $KMnO_4$, the product is formed. One mole of compound **A** also reacts with one mole of bromine in tetrachloromethane but does not react with Na.

Compound **B** is formed when $HC/(g)$ is added to compound **A**. Compound **B** is heated with aqueous NaOH to give compound **C**. Compound **C** does not react with acidified $K_2Cr_2O_7$.

Suggest the structures for **A-C**, and explain the observations described above.

[9]

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