NAME _____ CLASS **23S**

JURONG PIONEER JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION 2024

CHEMISTRY 9729/02

Paper 2 Structured Questions

10 September 2024
2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

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

For Examiner's Use	
1	/7
2	/11
3	/13
4	/14
5	/12
6	/18
Penalty (delete accordingly)	
Lack **3 sf** in final answer	**–1 / NA**
Missing/wrong **units** in final ans	**–1 / NA**
Bond linkages	**–1 / NA**
Total	/**75**

This document consists of **22** printed pages and **2** blank pages.

[Turn Over

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

For Examiner's Use

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

The most recent updates to the Periodic Table occurred in 2016, when IUPAC officially recognised the discovery of four new elements: Nihonium (Nh), Moscovium (Mc), Tennessine (Ts), and Oganesson (Og), completing the seventh row of the table.

Table 1.1 lists the number of protons, neutrons and electrons in four particles, each from one of the elements mentioned above.

Each particle may be an atom, an anion or a cation.

Table 1.1

element	particle	atomic no.	nucleon no.	no. of protons	no. of neutrons	no. of electrons
Nihonium (Nh)	**Nh**	113	286	113	173	113
Moscovium (Mc)	**Mc^{3-}**	115	290		175	118
Tennessine (Ts)	**Ts^{-}**	117			177	
Oganesson (Og)	**Og**		294	118		118

(a) Based on the positions of the four new elements in the Periodic Table, state the Group that each of the elements belong to.

Nh ……

Mc ……

Ts ……

Og …… [1]

(b) Fill in the empty spaces in Table 1.1. [2]

(c) A stream consisting of α-particles (He^{2+}) is subjected to an electric field as shown in Fig. 1.1 below.

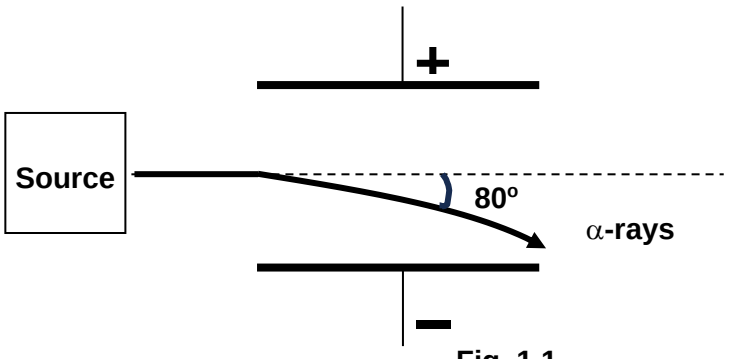

Fig. 1.1

Determine, by calculation, the angle of deflection for a second stream consisting of Mc^{3-} that is passed through the same electric field.

For Examiner's Use

[1]

(d) The simplified electronic configuration of Nihonium is given below.

Nh: [Rn] $5f^{14}\,6d^{10}\,7s^2\,7p^1$

(i) Using information from Table 1.1, give the simplified electronic configuration of Moscovium (Mc).

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…… [1]

(ii) Predict if Nh or Mc would have a higher first ionisation energy. Briefly explain your answer.

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…… [2]

[Total: 7]

For Examiner's Use

2 **(a)** Catalytic converters containing platinum solid convert over 90% of carbon monoxide and gaseous nitrogen oxides into harmless gases such as CO_2 and N_2. Outline the mode of action of the platinum catalyst.

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…… [2]

One reaction in which air can be polluted with nitrogen oxides is shown below.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

0.05 mol dm^{-3} of NO and 0.005 mol dm^{-3} of O_2 were mixed and the rate of reaction was followed by measuring the concentration of oxygen remaining after various time intervals.

The following graph was obtained in Fig. 2.1.

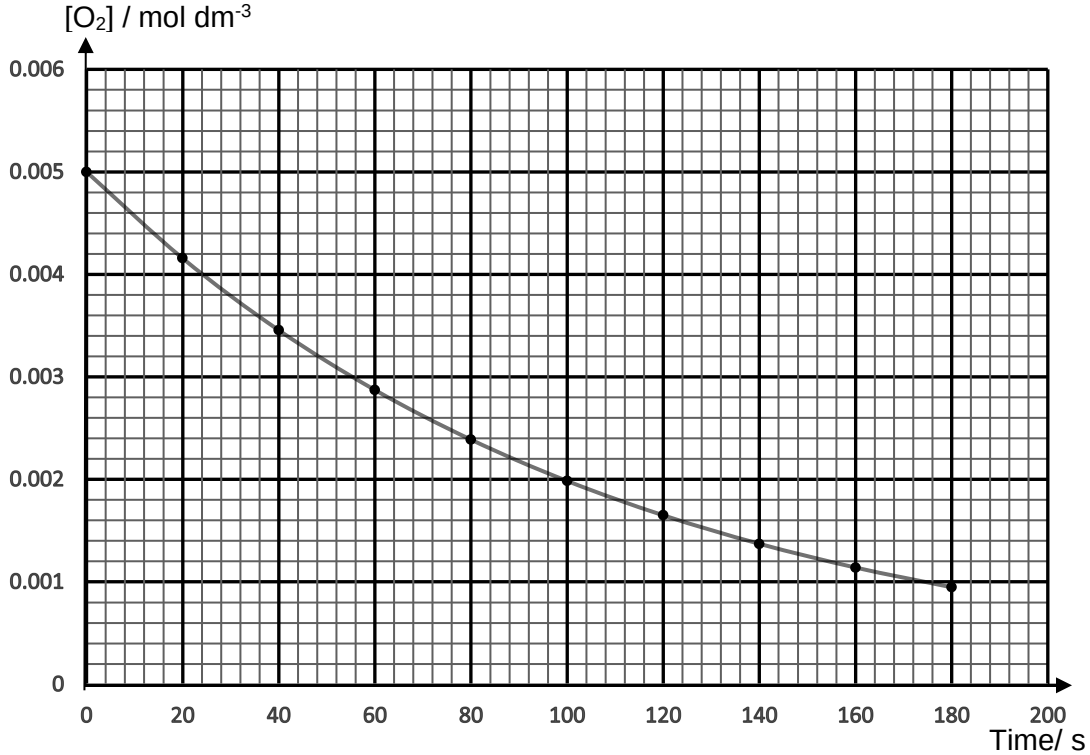

Fig. 2.1

(b) **(i)** Define the term *half-life* of a reaction.

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…… [1]

For Examiner's Use

(ii) Show all your working and draw clearly any construction lines on Fig. 2.1 to determine the order of reaction with respect to O_2.

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…… [2]

(iii) Show all your working and clearly draw any construction lines on Fig. 2.1 to determine the initial rate of reaction. State its units.

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…… [2]

(c) Further experiments were carried out changing the [NO] but keeping the initial $[O_2]$ constant at 0.10 mol dm^{-3}. The following results were obtained.

Table 2.1

Experiment	Initial [NO] / mol dm^{-3}	Initial rate / mol dm^{-3} min^{-1}
1	0.01	3.75×10^{-5}
2	0.02	1.50×10^{-4}

(i) Using the data from Table 2.1, deduce the order of reaction with respect to NO.

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…… [1]

(ii) Write the rate equation for this reaction.

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…… [1]

For Examiner's Use

(iii) Using Table 2.1, calculate a value for the rate constant. Include units of the rate constant in your answer.

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…… [1]

(d) Two possible mechanisms for this reaction are given below.

State the mechanism which is consistent with the rate equation you have written in **(c)(ii)** and explain your answer.

Mechanism **1**	
$2NO \rightleftharpoons N_2O_2$	(fast)
$N_2O_2 + O_2 \rightarrow 2NO_2$	(slow)

Mechanism **2**	
$NO + O_2 \rightarrow NO_2 + O$	(slow)
$O + NO \rightarrow NO_2$	(fast)

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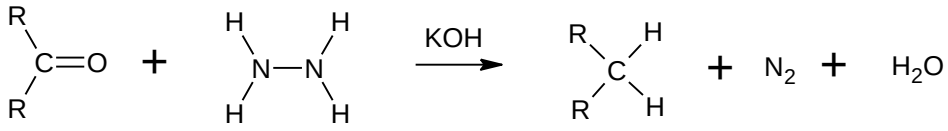
…… [1]

[Total: 11]

For Examiner's Use

3 The Wolff-Kishner reaction transforms ketones or aldehydes into alkanes by using hydrazine, N_2H_4 and potassium hydroxide, KOH, as illustrated in equation 1 below.

Equation 1



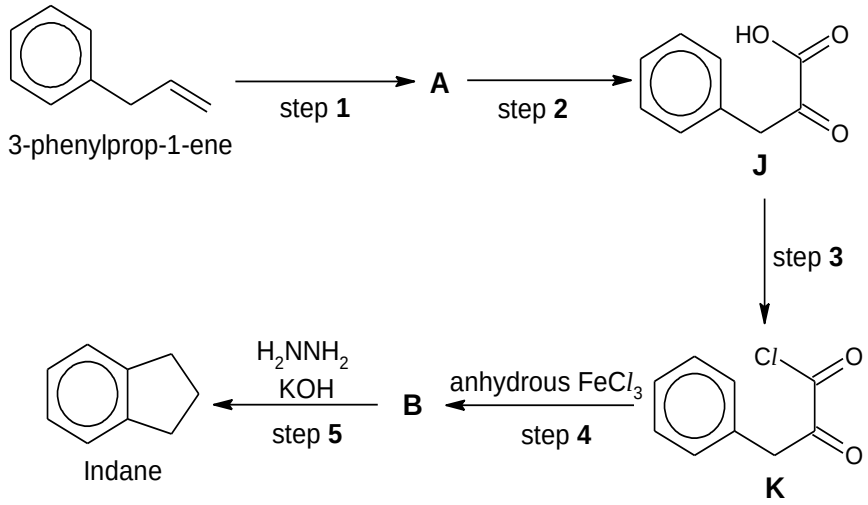
(a) State the type of reaction in equation 1.

……

[1]

(b) Indane, C_9H_{10}, is an ortho-fused bicyclic hydrocarbon consisting of a benzene ring fused to a cyclopentane ring. It is used as an anti-vibration agent for aviation fuel.

Indane can be synthesised from 3-phenylprop-1-ene by the following route, incorporating Wolff-Kishner reaction.



(i) Draw the structures of **A** and **B**.

[2]

(ii) State the reagents and conditions for steps **1**, **2** and **3**.

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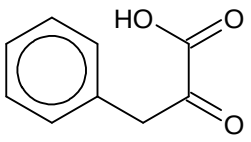
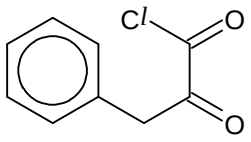
[3]

For Examiner's Use

(iii) By means of a simple chemical test, distinguish compounds **J** and **K**. State the observations for each compound clearly.



J



K

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…… [2]

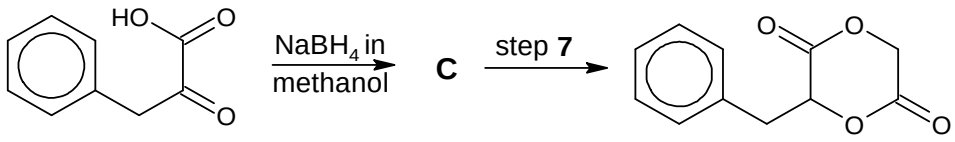
(c) Nitration of 3-phenylprop-1-ene can achieved by reacting it with concentrated H_2SO_4 and concentrated HNO_3.

Name and draw the reaction mechanism for the nitration of 3-phenylprop-1-ene.

[3]

For Examiner's Use

(d) Compound **J** can be used as a starting material to produce a cyclic diester as shown below.



(i) Draw the structure of **C**.

[1]

(ii) Suggest the reagents and conditions for step **7**.

……

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…… [1]

[Total: 13]

For Examiner's Use

4 (a) Compound **D** is a sweet-smelling organic compound with the molecular formula $C_5H_9BrO_2$. It is known that each molecule of **D** contains two functional groups.

A student from JPJC was tasked to determine the structure of compound **D**.

Table 4.1 below shows the chemical reactions that the student carried out for compound **D**.

Table 4.1

expt	reagent	Result
1	$AgNO_3$(aq), warm	cream precipitate formed which was soluble in an excess of NH_3(aq).
2	NaOH(aq), heat	two products were formed; **E** ($C_3H_5O_3Na$) and **F** (C_2H_6O).

(i) State the identity of the cream precipitate formed in experiment 1.

Hence or otherwise, name the functional group, shown by experiment 1, that is present in compound **D**.

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…… [1]

(ii) State the type of reaction undergone in reaction 2 and identify the other functional group in **D**.

……

…… [1]

The student conducted further chemical tests on compounds **E** and **F** separately. The results of the tests are given in Table 4.2.

Table 4.2

experiment	reagent	Result
3	PCl_5(s)	misty fumes were formed for both **E** and **F**.
4	I_2, NaOH(aq), warm	pale yellow precipitate formed for both **E** and **F**.

(iii) Based on both experiments **3** and **4**, what is the common functional group that could be present in both compounds **E** and **F**? Explain your answer, giving the type of reaction undergone.

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…… [1]

For Examiner's Use

(iv) Using your answers in **(a)(i)**, **(a)(ii) and (a)(iii)**, draw the structures of compounds **E** and **F**.

[2]

(v) The student now has enough information to determine the structural formula of **D**.

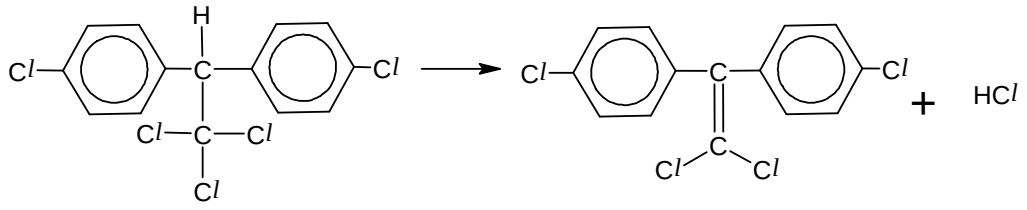
Draw the fully displayed structure of **D**.

[1]

For Examiner's Use

(b) Dichlorodiphenyltrichloroethane (DDT) is an organochlorine pesticide that was widely used during the 20th century for controlling insect-borne diseases like malaria.

The equation below shows the environmental degradation of DDT to dichlorodiphenyldichloroethylene (DDE).



DDT DDE

(i) State the type of reaction for the conversion of DDT to DDE.

……

…… [1]

Table 4.3 below shows the results when aqueous silver nitrate is heated with 0.5 mol of DDT and 0.5 mol of DDE separately.

Table 4.3

	Time taken for precipitate (ppt) to appear	No. of moles of ppt formed per mole of compound reacted
DDT	5 min	***x*** mol
DDE	no ppt	0 mol

(ii) State the value of ***x*** in Table 4.3.

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…… [1]

(iii) Explain why no precipitate was observed for the reaction with DDE.

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…… [2]

(iv) In organic chemistry, a geminal compound is a molecule in which 2 or more identical or similar functional groups are attached to the same carbon atom**.**

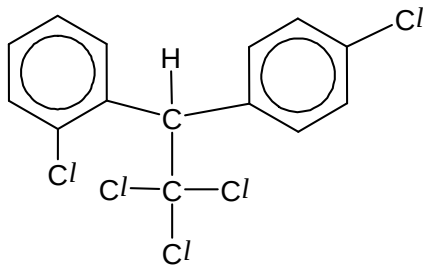
When DDT reacts with hot aqueous NaOH, a gem-triol, is formed as an intermediate. A gem-triol contains three -OH groups bonded to the same carbon atom. The gem-triol formed is unstable and it readily converts to the final product, **S**.

S reacts with aqueous Na_2CO_3(aq) to liberate a colourless gas.

Draw the structure of the organic compound **S**.

[1]

(c) **(i)** 1,1,1-trichloro-2-(2-chlorophenyl)-2-(4-chlorophenyl)ethane, or o,p'-DDT, is an constitutional isomer of DDT. The structure of o,p'-DDT is given below.



o,p'-DDT

State the type of stereoisomerism exhibited by o,p'-DDT.

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…… [1]

(ii) Draw the stereoisomers of o,p'-DDT.

[2]

[Total: 14]

For Examiner's Use

5 The pH of the seawater in the ocean is regulated by the carbonate - bicarbonate (CO_3^{2-} / HCO_3^-) buffer system.

Main buffering system:

$$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$$

Recently, changes in the pH of the oceans by ocean acidification has been a concern. Ocean acidification, primarily caused by the absorption of carbon dioxide, CO_2, from the atmosphere, poses a significant threat to marine ecosystems worldwide.

The increased concentration of CO_2 in seawater leads to changes in the pH as shown in Fig. 5.1 below which shows the average ocean pH level worldwide from 1985 to 2020.

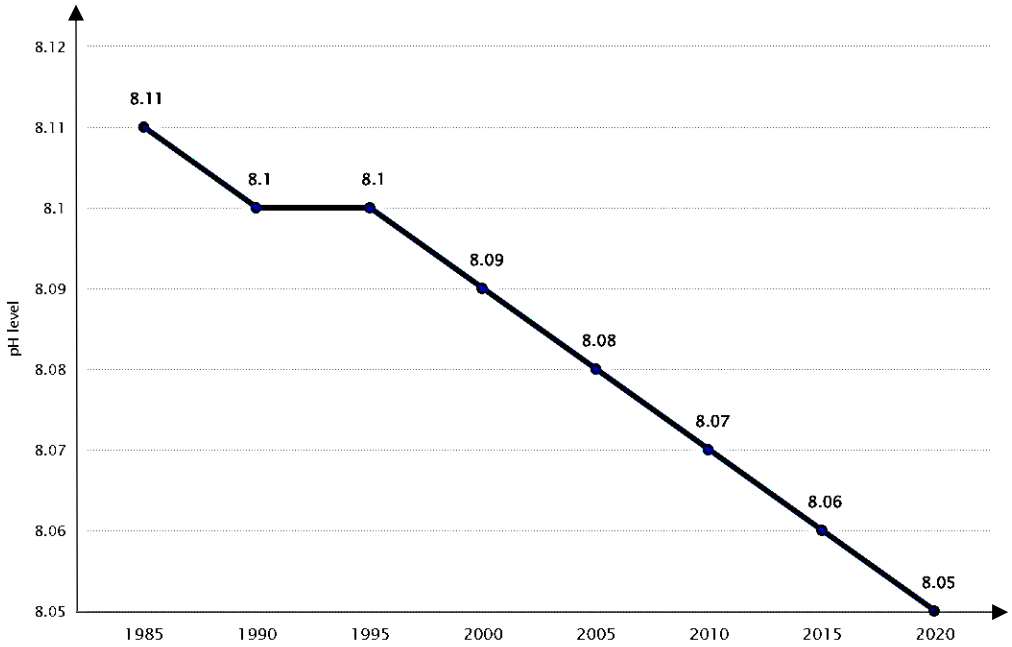

Fig. 5.1

(a) (i) Using Fig. 5.1, state and explain the trend of the pH of the seawater of the ocean.

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…… [1]

(ii) With the aid of equations show how the carbonate - bicarbonate buffer system in seawater maintains the pH when there is an increase in amounts of H^+ or OH^- in the seawater.

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…… [2]

(iii) Use the pH value from Fig. 5.1, show that the molar ratio of bicarbonate to carbonate ion of a sample of seawater from 2020 is 89:1.

Given that the K_b of CO_3^{2-} is 1.0×10^{-4} mol dm^{-3}.

[2]

The total CO_3^{2-} + HCO_3^- content of the seawater can be found by boiling a seawater sample with an excess of dilute sulfuric acid and absorbing the CO_2 evolved in a solution of barium hydroxide, $Ba(OH)_2$.

The precipitated barium carbonate, $BaCO_3$ can be filtered off, dried and weighed.

When a 100 cm^3 seawater sample was treated in the above-mentioned process, 0.281 g of $BaCO_3$ was produced.

[Assume that the seawater sample is from the year 2020]

(iv) Show that the total amount of CO_3^{2-} + HCO_3^- content in the seawater sample is 1.42×10^{-3} mol.

[1]

(v) Hence, using the information in **(a)(iii) & (a)(iv)** calculate [CO_3^{2-}] in the 100 cm^3 seawater sample from 2020.

[2]

For Examiner's Use

(b) Organisms with calcium carbonate shells produce their shells according to the equation shown.

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$$

Changes in the pH alters the chemical balance of the oceans and affects marine life, particularly organisms with calcium carbonate shells.

(i) Using the equations below and the concept of Le Chatelier's principle and solubility product, explain why marine organisms will not be able to build shells if pH of the seawater decreases.

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightleftharpoons CaCO_3(s) \quad \text{------(1)}$$

$$HCO_3^{-}(aq) \rightleftharpoons CO_3^{2-}(aq) + H^{+}(aq) \quad \text{------(2)}$$

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…… [2]

(ii) The concentration of Ca^{2+} ions in the seawater sample from 2020 is 3.99×10^{-4} mol dm^{-3}.

Given that K_{sp} $CaCO_3$ is 3.30×10^{-9} mol^2 dm^{-6}, calculate the minimum $[CO_3^{2-}]$ for the organisms to form their shells in 2020.

[1]

(iii) Using your answer in **(a)(v)** and **(b)(ii)**, explain whether the organisms will be able to form their shells in the seawater in 2020?

[1]

[Total: 12]

For Examiner's Use

6 **(a)** Haemoglobin and hemocyanin are two oxygen-transporting proteins found in living organisms. Both proteins are coloured due to the presence of transition metals, such as iron in haemoglobin and copper in hemocyanin, that form complexes essential for their oxygen-binding properties.

(i) Why are transition metal complexes coloured?

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…… [3]

(ii) Non-transition metal compounds, in contrast, tend to be colourless.

Explain why a solution containing $[Mg(H_2O)_6]^{2+}$ is colourless.

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…… [1]

Absorption spectra, an analytical method in chemistry, show the wavelengths of light absorbed by substances.

Chemists use this technique to analyse the oxygenated blood samples from sheep (haemoglobin) and spiders (haemocyanin) to compare their absorption characteristics.
The result of the analysis is shown in Fig. 6.1.

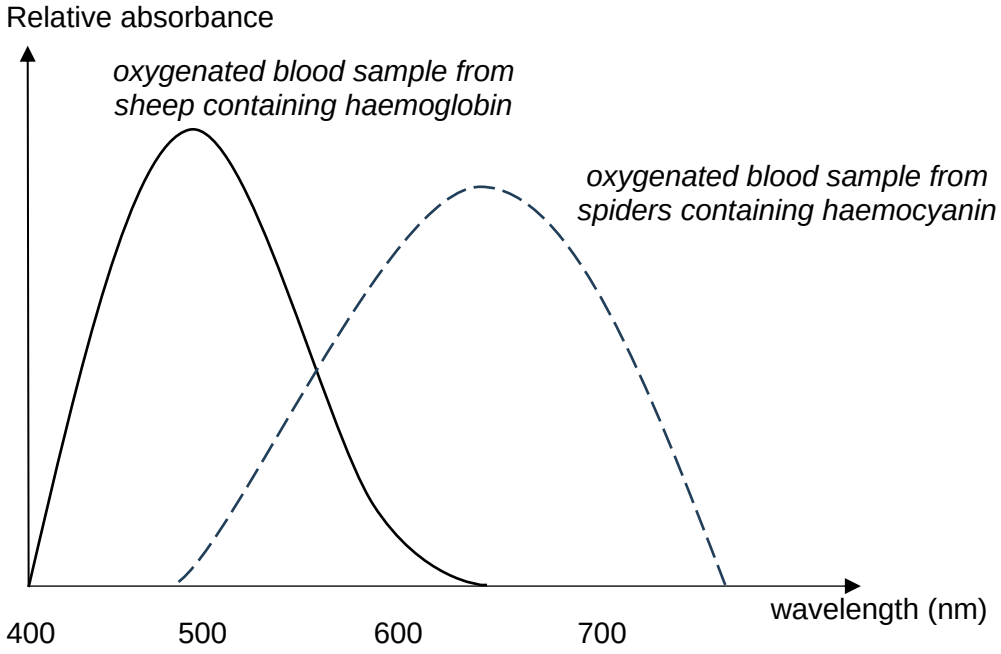

Fig. 6.1: Graph showing Absorption Spectra

The wavelengths associated with each colour of visible light are given below in Table 6.1. Light of a longer wavelength is lower in energy than light of a shorter wavelength.

Table 6.1

colour of visible light	wavelength (nm)
Red	620 – 750
Orange	590 – 620
Yellow	570 – 590
Green	495 – 570
Blue	450 – 495
Violet	380 – 450

(iii) The oxygenated blood of sheep, which contains haemoglobin, is red.

Using this information and the data provided, predict the colour of the oxygenated blood of spiders, which contains haemocyanin.

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…… [1]

For Examiner's Use

(iv) What deduction can be made from the absorption spectra in Fig. 6.1, about the size of the d-orbital splitting in the two samples of oxygenated blood, containing different complexes of haemoglobin and haemocyanin?

Explain your answer.

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[2]

For Examiner's Use

(b) The van Arkel triangle, invented by Dutch chemist Anton Eduard van Arkel, is a tool used to classify the bonding in compounds as ionic, covalent, or metallic.

Fig. 6.2 shows an example of a van Arkel triangle.

The y-axis represents the difference in electronegativity between two elements, while the x-axis shows the average electronegativity of the two elements.

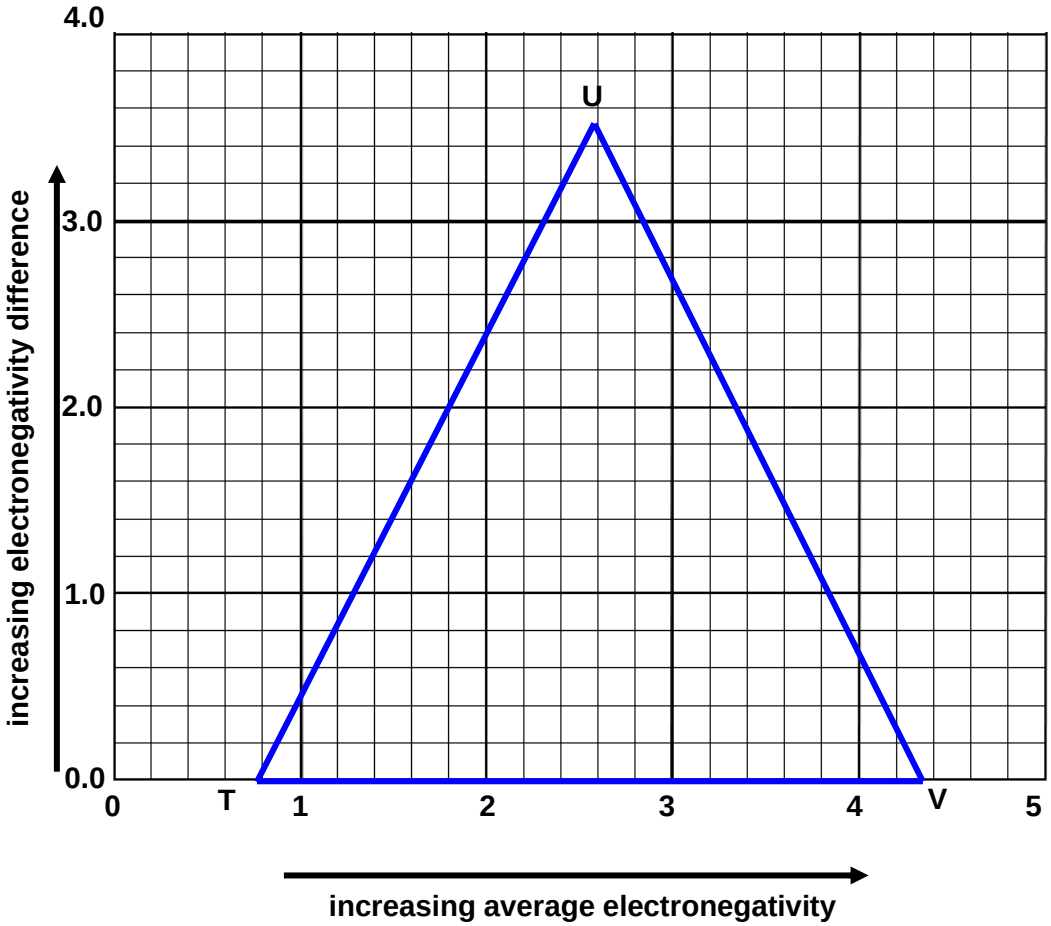

Fig. 6.2

Table 6.2 provides the electronegativity values of some of elements from Period 3 of the Periodic Table, based on Pauling's Scale. The average electronegativity is calculated based on the sum of the electronegativities of the two elements in the compound, divided by two.

Table 6.2

Element	Electronegativity
Na	0.9
Mg	1.2
A*l*	1.5
Si	1.8
P	2.1
S	2.5
C*l*	3.0

For Examiner's Use

(i) Plot the position of CCl_2 and $AlCl_3$ on the diagram. Label your points clearly in Fig. 6.2.

[2]

(ii) The three extremes on the van Arkel triangle, namely **T**, **U** and **V**, represent the three types of chemical bonding, metallic, ionic and covalent.

State the correct type of bonding present at each of the bonding extremes.

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…… [2]

(c) **(i)** In the liquid state, $AlCl_3$ exists as a compound with a molar mass of 267 g mol^{-1}.

Draw the structure of this compound.

[1]

(ii) The boiling points of Al_2O_3 and $AlCl_3$ in the liquid state are 2977 ^oC and 180 ^oC respectively.

Explain, in terms of structure and bonding, the difference in their boiling points.

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…… [2]

For Examiner's Use

(iii) The pH values of the solutions of two Period 3 chlorides are given below in Table 6.3.

Table 6.3

compound	pH of 1.0 mol dm^{-3} solution
$MgCl_2$	**X**
$AlCl_3$	**Y**

Write equations for the reaction of $AlCl_3$ with water.

State the values of x and y in Table 6.3 above. Briefly explain the different pH values of the two chloride solutions.

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…… [3]

(iv) The lattice energy of magnesium chloride is –2582 kJ mol^{-1}. Some enthalpy changes of hydration are listed in Table 6.4.

Table 6.4

Ions	ΔH_{hyd} / kJ mol^{-1}
Mg^{2+}	–1980
Cl^-	–381

Using the data provided, calculate the enthalpy change of solution of magnesium chloride*.*

[1]

[Total: 18]

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