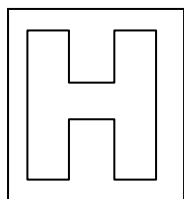


Candidate Name: _____

Class Adm No

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2021 Preliminary Examinations

Pre-University 3

H2 CHEMISTRY

Paper 3 Free Response

9729/03

17 Sep 2021

2 hours

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.

Section A: Answer **all** questions

Section B: Answer any **1** question

A Data Booklet is provided.

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

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

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.

	Section A			Section B		Total
Question	1	2	3	4	5	
Marks	24	20	16	20	20	80

Section A

Answer **all** questions from this section.

- 1 (a) A metallic element, **M**, exists as three isotopes. The relative isotopic masses and their relative abundances are shown in Table 1.1.

Relative Isotopic Mass	Relative Abundance
53.94	3
55.93	46
56.94	1

Table 1.1

- (i) Define the term *relative isotopic mass*. [1]
- (ii) Using the information in **Table 1.1**, calculate the relative atomic mass of **M**, leaving your answer to 2 decimal places. [1]

A dilute aqueous solution of the chloride salt of **M**, MCl_n , was electrolysed using a current of 0.5 A for 1 hour as shown in the setup in **Fig. 1.1**. The experiment was carried out at 32 °C and 1 atm.

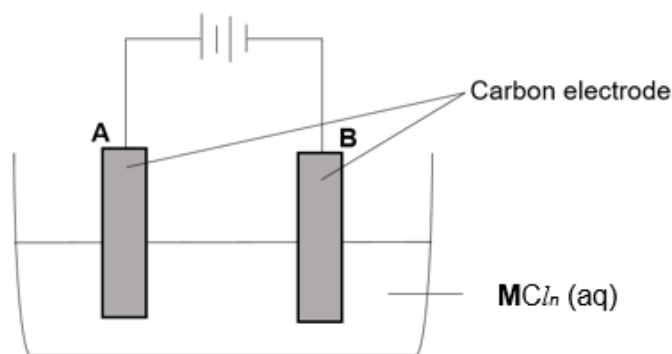


Fig. 1.1

0.3471 g of metal **M** was deposited at electrode **B**.

- (iii) Using your answer in (a)(ii), determine n . [3]
- (iv) A gas is produced at electrode **A**.
Write the ion-electron equation for the reaction taking place at electrode **A**. [1]
- (v) Calculate the volume of gas produced at electrode **A**. [2]
- (vi) Suggest why electrode **A** will decrease in mass over time. [1]

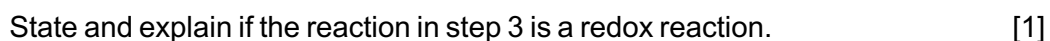
Table 1.2

- (i) Give one characteristic properties of transition elements as shown by chromium in the isomers in **Table 1.2**. [1]
- (ii) Using $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$, explain what is meant by the term *ligand*. [1]
- (iii) When 2.665 g of one of the complexes in **Table 1.2** was reacted with an excess of aqueous AgNO_3 , 2.868 g of AgCl was obtained.
- Deduce the structural formula of the complex. [2]
- (iv) Draw the full structure of the cation in the pale green complex, $[\text{CrCl}(\text{H}_2\text{O})_5]\text{Cl}_2 \cdot \text{H}_2\text{O}$, showing the shape of the cation. [1]

This image shows a full page of white paper with horizontal dashed lines, typical of primary school writing paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

(i) Write the ion-electron equation for the oxidation of Cr^{3+} in step 1 and hence the overall balanced equation for the reaction between Cr^{3+} and H_2O_2 under alkaline conditions. [2]

(iii) The reaction in step 3 has the following equation:



State and explain the effect of increasing the temperature of the system on the yield of $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$. [2]

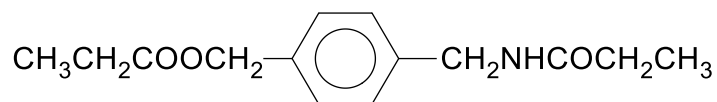
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- [illegible]

[Total: 24]

- 2 (a)** Compound **P**, $\text{C}_8\text{H}_9\text{NO}$, can react with Tollen's reagents but not with Fehling's solution. **P** is also soluble in dilute hydrochloric acid.

On reacting **P** with lithium aluminium hydride, **Q**, $\text{C}_8\text{H}_{11}\text{NO}$, is formed. **Q** reacts readily with sodium metal. 1 mole of **Q** reacts with 2 moles of propanoyl chloride to give the following compound.

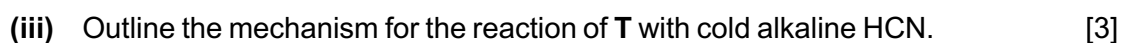
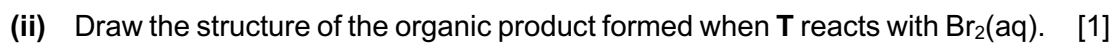
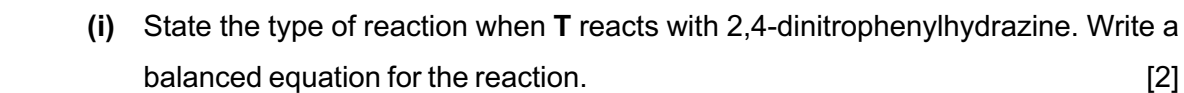


Q also reacts with hot acidified KMnO_4 to give **R**, $\text{C}_8\text{H}_6\text{O}_4$. 1 mole of **R** reacts with excess $\text{Na}_2\text{CO}_3(\text{s})$ to give 1 mole of $\text{CO}_2(\text{g})$.

When **P** is heated with excess CH_3Br , a crystalline solid **S**, $\text{C}_{11}\text{H}_{16}\text{NOBr}$, is formed. **S** has very high melting point.

Deduce the structure of compounds **P**, **Q**, **R** and **S**, explaining the chemistry of the reactions described. [10]

[illegible]

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3 This question involves sulfur and its compounds.

(a) (i) State the full electronic configuration of S^{3+} . [1]

(ii) Write an equation to represent the fourth ionisation energy of sulfur. [1]

(iii) The fourth ionisation energy of sulfur and phosphorus is 4540 kJ mol^{-1} and 4960 kJ mol^{-1} respectively.

Explain why the fourth ionisation energy of sulfur is lower than that of phosphorus. [2]

(iv) A sample of S contains 2 isotopes. In order to identify the mass of these two isotopes, they were first ionised to form singly-charged positive ions and passed through an electric field of constant strength. Their angles of deflection, along with a reference sample of helium nucleus, ${}^4_2\text{He}$, were recorded in Table 3.1.

Species	Angle of deflection
Isotope X	1.60°
Isotope Y	1.51°
Helium nucleus, ${}^4_2\text{He}$	25.6°

Table 3.1

Calculate the relative mass of each isotope of sulfur, giving your answer to the nearest whole number. [3]

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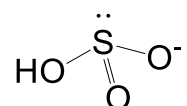
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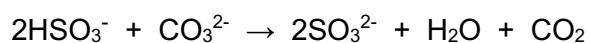
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(b) Hydrogen sulfite ion, HSO_3^- , has the following structure:



Hydrogen sulfite ion reacts with carbonate ion according to the following equation:



- (i) Define the term *Brønsted-Lowry acid*. [1]
- (ii) State which species in the reaction between hydrogen sulfite ion and carbonate ion acts as a Brønsted-Lowry acid. [1]
- (iii) The carbon dioxide gas produced from the reaction is a non-ideal gas. **Fig. 3.1** shows the experimental values of the compressibility factor (Z) plot for 1 mole of carbon dioxide gas at 298 K. ($Z = pV/RT$)

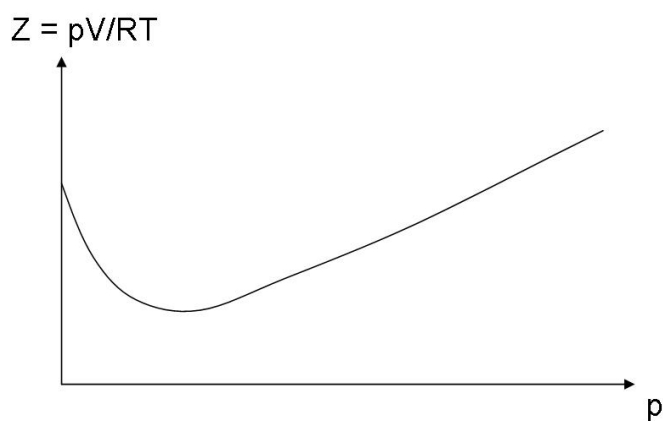


Fig. 3.1

On the plot given in **Fig. 3.1**, sketch the graph to illustrate the behaviour of

- I. 1 mole of an ideal gas at 298 K,
- II. 1 mole of carbon dioxide gas at 398 K.

Label your answer clearly.

[2]

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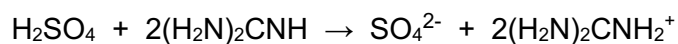
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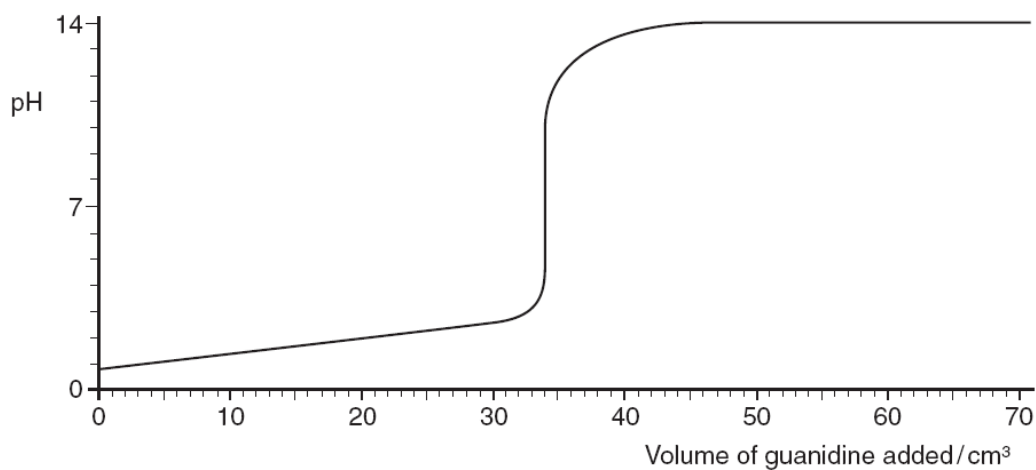
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(c) Sulfuric acid reacts with guanidine, $(\text{H}_2\text{N})_2\text{CNH}_2$, as follows:



When a 25.0 cm^3 sample of dilute sulfuric acid was titrated against a solution of guanidine, the following titration curve was obtained.

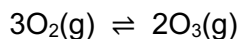


- [Total: 16]

Section B

Answer **one** question from this section.

- 4 In the stratosphere, there is an equilibrium established between O_2 and O_3 :



When UV radiation from the sun breaks up O_3 into an oxygen atom and an oxygen molecule, the oxygen atom quickly recombines with an oxygen molecule to form back ozone. However, this equilibrium is disrupted by the radicals produced from the chlorofluorocarbons (CFCs) due to human activities.

- (a) One such CFC is CF_2Cl_2 .

Write two equations to illustrate how CF_2Cl_2 , in the presence of UV light, causes the decomposition of ozone layer. [2]

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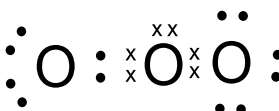
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- (b) The dot-and-cross diagram of O_3 is shown below.



With the aid of suitable diagram, explain why the two oxygen-oxygen bonds in the ozone molecule have the same bond strength. [2]

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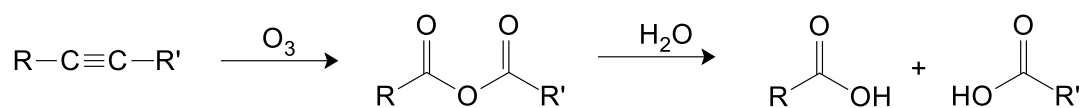
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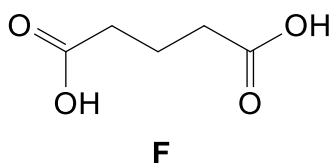
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- (d) Ozone reacts with alkynes to form carboxylic acids in a two-step reaction as shown below.



When alkyne **E** undergoes the same two-step reaction, only compound **F** is formed.



Suggest the structure of **E**.

[1]

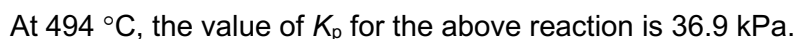
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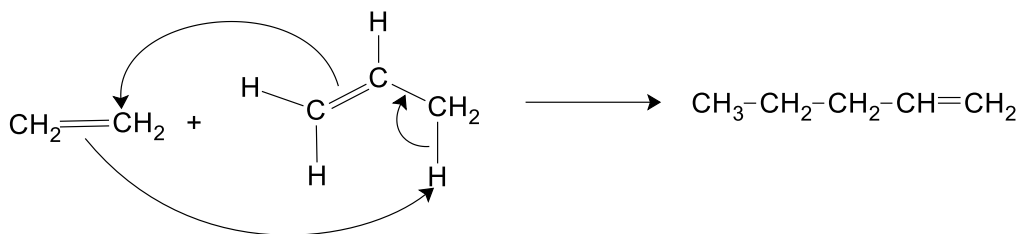
When a certain partial pressure of nitrogen dioxide is put into an empty vessel at 494 °C, equilibrium is reached when 40% of the original nitrogen dioxide has dissociated.

- (i) Write an expression for the equilibrium constant, K_p , for the reaction. [1]
- (ii) Calculate the initial partial pressure of nitrogen dioxide before any dissociation occurred. [2]
- (iii) Given that the standard enthalpy change of formation of $\text{NO}(\text{g})$ is $+90.3 \text{ kJ mol}^{-1}$, determine the standard enthalpy change of formation of $\text{NO}_2(\text{g})$. [2]
- (iv) With reference to the equation given in (e), state and explain the sign of entropy change, ΔS , for the dissociation of $\text{NO}_2(\text{g})$. [1]
- (v) Using your answer in (e)(iv), state whether the reaction would be spontaneous at high or low temperatures. [1]

[Total: 20]

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- 5 (a) Aluminium chloride is used in the production of chlorobenzene from the reaction between benzene and chlorine.
- (i) Outline the mechanism for the reaction above. [3]
- (ii) Explain, with the aid of relevant equations, why the aluminium chloride used in the above reaction must be anhydrous. [2]
- (iii) Aluminium chloride can also act as a catalyst for the Alder-ene reaction. One example of Alder-ene reaction is illustrated below using propene and ethene.



Suggest the structure of the organic product formed when cyclohexene reacts with ethene in an Alder-ene reaction. [1]

[illegible]

Explain how this adduct is formed.

[illegible]

[illegible]

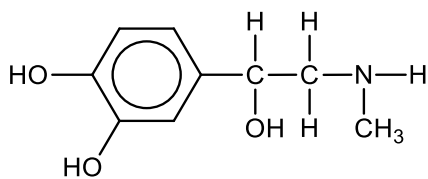
- $$\text{Mg}(\text{NO}_3)_2(\text{aq}) + 2\text{NaOH}(\text{aq}) \rightarrow \text{Mg}(\text{OH})_2(\text{s}) + 2\text{NaNO}_3(\text{aq})$$

The value of K_{sp} of magnesium hydroxide is 1.5×10^{-11} .

- (i) Write an expression for the K_{sp} of magnesium hydroxide, stating its units. [2]
- (ii) Calculate the concentration of hydroxide ions that remained in the **filtrate**. [2]
- (iii) Calculate the concentration of magnesium ions that remained in the **filtrate**. [1]
- (iv) Hence, calculate the mass of solid magnesium hydroxide formed. [2]

[illegible]

(e) The structure of compound **L** is shown below.



Compound L

Draw the structure of the organic product formed when compound **L** reacts with the following reagents.

- (i) SOCl_2 [1]
(ii) Bromine water [1]

[Total: 20]

[illegible]

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