CHEMISTRY

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 provided on the Question Paper.

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

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

This document consists a total of 11 printed pages.

1	(a)	Cadmium sulfide (CdS) is a toxic yellow pigment. Some data concerning CdS is printed below.	
		K_{sp} at 298 K = 1.00 × 10 ⁻²⁸ Melting point: 2020 K	
	(i)	Explain why CdS has a high melting point.	[2]
	(ii)	Calculate the solubility, in grams per cubic decimeters, of CdS at 298 K.	[2]

(b)	The aqua Cd^{2+} ion, represented as $Cd(H_2O)_6^{2+}$ shows acidic properties in water. The p K_a of this ion is 10.1.	
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(c)	Although cadmium sulfide has poor solubility in water, its solubility was observed to have increased significantly when CdS is dissolved in a solution of hydrochloric acid.	
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 	 [Total: 10]

2 (a) Volhard's method is a common method used to determine the concentration of chloride ions in a given solution.

A contaminated sample ${\bf X}$ contains sodium chloride and sodium carbonate, and other unknown impurities.

Part 1: Determination of percentage mass of sodium carbonate

0.500 grams of **X** was dissolved in water and made up to a 250 cm³ solution.

25.0 cm³ of solution was withdrawn into a conical flask, and titrated against a standard solution of 0.0500 mol dm⁻³ hydrochloric acid, with the indicator being methyl orange.

Some data concerning carbonic acid, H₂CO₃, is shown below:

$$pK_1 = 6.35$$

 $pK_2 = 10.33$

The results were tabulated as follows:

Titre no.	1	2
Volume of HCl used / cm ³	15.30	15.40

In the titrations, 3 reactions took place regarding sodium carbonate.

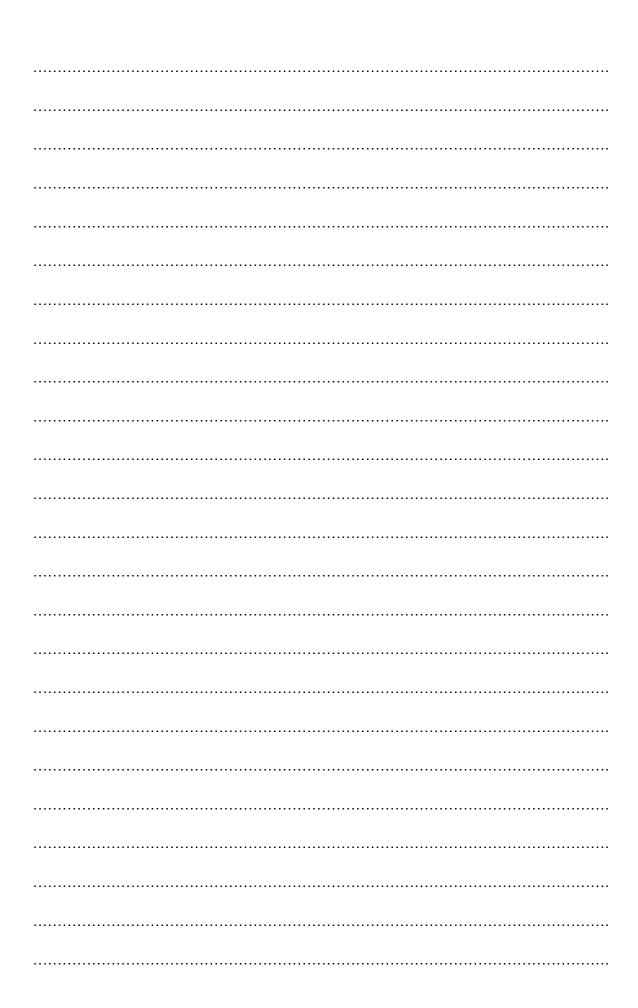
Reaction 1: $CO_3^{2-} + H^+ \rightarrow HCO_3^-$ **Reaction 2**: $HCO_3^- + H^+ \rightarrow H_2CO_3$ **Reaction 3**: $H_2CO_3 \rightleftharpoons CO_2 + H_2O$

- (i) Calculate, by percentage of mass, the purity of sodium carbonate in **X**. [2]
- (ii) Hence, sketch a graph of pH of the solution against volume of HC*l* added. [4]

You should include all pH values of vital points where they are possible to calculate.

(iii) State an essential assumption you made in your calculations. [1]

(iv)	Phenolphthalein is also a suitable indicator that can be used for this titration. However, this indicator only detects the endpoint of Reaction 1 .		
	Suggest why phenolphthalein isn't used as an indicator.	[1]	
(v)	Explain why carbon dioxide was only produced in the later half of the titration.	[1]	



(b)	when aluminium chloride is added to a solution of sample X , effervescence was observed. A white precipitate of aluminium hydroxide is observed too.		
	The p K_a value of the aluminium ion is 4.27.		
(i)	Explain, with appropriate pK_a values, why aluminium hydroxide is the product.	[2]	
(ii)	Explain qualitatively why aluminium carbonate is a very unstable salt.	[2]	

(c) Part 2: Determination of the amount of sodium chloride by the Volhard Method

25.0 cm³ of the solution in the volumetric flask in Part 1 was pipetted into a conical flask. 10.00 cm³ of 0.100 mol dm⁻³ of hydrochloric acid was added.

25.0 cm³ of 0.100 mol dm⁻³ of silver nitrate was then added into the conical flask. The resultant solution was then filtered, and the filtrate was collected. 0.100 cm³ of 0.100 mol dm⁻³ iron(III) nitrate was then added to the filtrate.

The filtrate was then titrated against 0.0100 mol dm⁻³ of potassium thiocyanate (KSCN). At the endpoint, the solution turns slightly red, due to the formation of the iron(III) thiocyanate complex ion, Fe(SCN)²⁺.

The average titre value obtained is 23.40 cm³.

Some data is provided below:

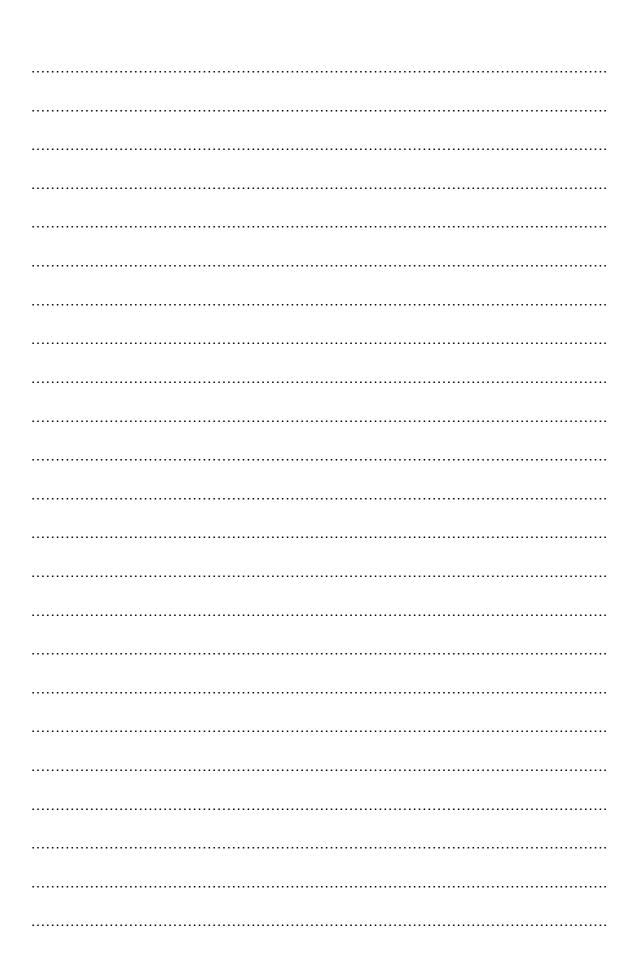
$$K_{\rm sp} ({\rm AgC} l) = 2.02 \times 10^{-10}$$

$$K_{\rm sp}$$
 (AgSCN) = 1.03 × 10⁻¹²

- (i) The Volhard method needs to be conducted in an acidic environment. Show that an acidic environment has been established.
- (ii) Calculate the percentage by mass of sodium chloride in **X**. [3]

[1]

- (iii) Explain, using the data provided, why it is advisable to filter off the silver chloride precipitate before commencing the precipitation titration like that in the description. [1]
- (iv) The silver chloride precipitate can be dissolved in aqueous ammonia. Explain how so. [2]



(d)	Mohr's method is another way to determine the concentration of chloride ions in a solution.	
	A 25.0 cm 3 of 0.100 mol dm $^{-3}$ sodium chloride solution was titrated against 0.100 mol dm $^{-3}$ silver nitrate solution. Before the titration, 0.100 cm 3 of 0.100 mol dm $^{-3}$ of K $_2$ CrO $_4$ was added. At the endpoint, a slight orange precipitate (Ag $_2$ CrO $_4$) is formed.	
	$K_{\rm sp}$ (Ag ₂ CrO ₄) = 3.01 × 10 ⁻¹²	
(i)	Given that the volume of titrant needed to reach the endpoint is 25.0 cm³, find the concentration of Ag⁺ present in the solution at the endpoint.	[1]
(ii)	Hence, calculate the percentage of chloride ions that have precipitated out at the endpoint to 2 decimal places, and comment on whether Mohr's method is a good method to accurately determine the concentration of chloride ions.	[2]
(iii)	Explain why AgCl precipitates first before Ag ₂ CrO ₄ .	[1]
(iv)	Explain if this method can be used if an unknown concentration of sulfate ions had to be determined instead.	[1]
	$K_{\rm sp}$ (Ag ₂ SO ₄) = 1.20 × 10 ⁻⁵	

[Total: 25]