



CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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9701/52

February/March 2024

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

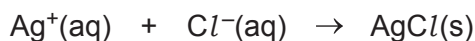
- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **12** pages. Any blank pages are indicated.

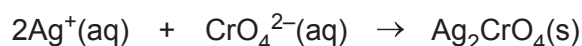
- 1 Sea water contains about 20 g dm^{-3} of chloride ions, $\text{Cl}^{-}(\text{aq})$.

The exact concentration of $\text{Cl}^{-}(\text{aq})$ in sea water can be determined by titration with aqueous silver ions, $\text{Ag}^{+}(\text{aq})$, using aqueous potassium chromate(VI), $\text{K}_2\text{CrO}_4(\text{aq})$, as an indicator.

When aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$, is added to a sample of sea water, silver ions react with chloride ions to form a precipitate of silver chloride.



When all of the $\text{Cl}^{-}(\text{aq})$ has reacted with $\text{Ag}^{+}(\text{aq})$, the presence of unreacted $\text{Ag}^{+}(\text{aq})$ is detected by chromate(VI) ions, $\text{CrO}_4^{2-}(\text{aq})$. A red precipitate of $\text{Ag}_2\text{CrO}_4(\text{s})$ is seen.



The amount of $\text{Ag}^{+}(\text{aq})$ reacting with $\text{Cl}^{-}(\text{aq})$ in the sample of sea water can be calculated in order to determine the concentration of $\text{Cl}^{-}(\text{aq})$ in the sample of sea water.

A student uses the following method.

- step 1** Use a weighing boat to weigh by difference approximately 10.6 g of $\text{AgNO}_3(\text{s})$ into a 100 cm^3 glass beaker.
- step 2** Use the sample of $\text{AgNO}_3(\text{s})$ in the glass beaker to prepare 250.0 cm^3 of $\text{AgNO}_3(\text{aq})$.
- step 3** Transfer this solution into a dark brown glass bottle. Label this solution **X**.
- step 4** Collect a sample of sea water and remove any solid material present.
- step 5** Transfer 10.00 cm^3 of the sea water into a conical flask.
- step 6** Add 1 cm^3 of $\text{K}_2\text{CrO}_4(\text{aq})$ to the conical flask.
- step 7** Rinse a burette in preparation for the titration.
- step 8** Fill the burette with solution **X**.
- step 9** Slowly add solution **X** to the conical flask until the white precipitate turns red. This is the end-point.

- (a) Describe how the student should carry out step 1. Include a table in your answer to show how this process is recorded.

.....

[2]

- (b) Describe how the student should prepare 250.0 cm^3 of $\text{AgNO}_3(\text{aq})$ in step 2, starting with the $\text{AgNO}_3(\text{s})$ in the 100 cm^3 beaker in step 1.

.....

[3]

- (c) Suggest why solution **X** is kept in a dark brown glass bottle in step 3 rather than a colourless glass bottle.

..... [1]

- (d) Suggest how solid material should be removed from sea water in step 4.

..... [1]

- (e) Identify the most appropriate piece of equipment that you would use to:

- (i) transfer 10.00 cm^3 of sea water from the dark brown bottle to a conical flask in step 5

..... [1]

- (ii) add 1 cm^3 of $\text{K}_2\text{CrO}_4(\text{aq})$ to the conical flask in step 6.

..... [1]

- (f) Chromate(VI) solutions are known to be carcinogenic. State what precaution should be taken when using $\text{K}_2\text{CrO}_4(\text{aq})$ in step 6 other than wearing safety goggles.

..... [1]

- (g) State what the burette should be rinsed with in step 7.

..... [1]

(h) The student obtains the results shown in Table 1.1.

Table 1.1

	rough titration	titration 1	titration 2	titration 3
final volume / cm ³	23.40	45.75	22.60	45.05
initial volume / cm ³	0.00	23.40	0.00	22.60
titre / cm ³				

(i) Complete Table 1.1. [1]

(ii) Calculate the mean titre to be used in the calculations. Show your working.

mean titre = cm³ [1]

(iii) Use the mean titre from (h)(ii) to calculate the concentration of chloride ions in the sample of sea water.

Assume the mass of solid silver nitrate used in step 2 was 10.62 g.

concentration = mol dm⁻³ [3]

(iv) Calculate the percentage error in the titre in titration 2.
Show your working.

percentage error = % [1]

(i) Spectroscopic analysis of the sample of sea water accurately determined the concentration of Cl⁻(aq) to be lower than that determined by titration with Ag⁺(aq).

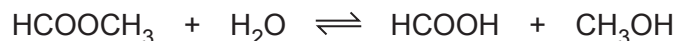
Suggest why the student's method gave a higher value.

.....

..... [1]

[Total: 18]

- 2 A student wants to investigate the rate of the hydrolysis of methyl methanoate, HCOOCH_3 .



The reaction is catalysed by dilute hydrochloric acid, HCl(aq) .

The amount of methanoic acid, HCOOH , produced as the reaction progresses can be monitored by titration with aqueous sodium hydroxide, NaOH(aq) , of known concentration using thymolphthalein as the indicator.

To determine this, the volume of NaOH(aq) needed to neutralise the $\text{H}^+(\text{aq})$ from the catalyst needs to be found beforehand.

The student uses the following procedure.

step 1 Add approximately 150 cm^3 of iced water to a 250 cm^3 conical flask, **A**.

step 2 Add 200 cm^3 of 0.250 mol dm^{-3} HCl(aq) to a 500 cm^3 conical flask, **B**.

Conical flask **B** is the flask in which the reaction takes place.

step 3 Transfer 2.00 cm^3 of 0.250 mol dm^{-3} HCl(aq) from conical flask **B** to conical flask **A**. Carry out a single titration of the contents of conical flask **A** with NaOH(aq) of known concentration.

step 4 Add 10.0 cm^3 of methyl methanoate to conical flask **B**, swirl the reaction mixture and immediately start a stopwatch.

step 5 After 1 minute transfer 2.00 cm^3 of the reaction mixture from conical flask **B** into conical flask **A**. Carry out a further single titration of the contents of conical flask **A** against NaOH(aq) . Do **not** empty the contents of conical flask **A** between titrations.

step 6 After 10 minutes transfer 2.00 cm^3 of the reaction mixture from conical flask **B** into conical flask **A**. Titrate the contents of conical flask **A** against NaOH(aq) .

step 7 Repeat step 6 at intervals of 10 minutes for 1 hour.

- (a) State which step is used to determine the concentration of $\text{H}^+(\text{aq})$ ions from the catalyst in the mixture.

..... [1]

- (b) The iced water in conical flask **A** is used to significantly reduce the rate of reaction.

Suggest **two** reasons why the rate of reaction is significantly reduced when the reaction mixture is transferred to conical flask **A**.

reason 1

.....

reason 2

.....

[2]

(c) Table 2.1 shows the readings taken by the student.

The titrations in steps 4–7 show the volume of NaOH(aq) needed to neutralise both the $\text{H}^+(\text{aq})$ ions from the catalyst, $\text{HCl}(\text{aq})$, and from the HCOOH produced in the reaction.

volume of NaOH(aq) needed, in cm^3 , to neutralise $\text{H}^+(\text{aq})$ from catalyst = 11.40 cm^3

volume of NaOH(aq), in cm^3 , used to neutralise $\text{H}^+(\text{aq})$ from HCOOH at time, $t = V_t$

volume of NaOH(aq), in cm^3 , used to neutralise $\text{H}^+(\text{aq})$ from HCOOH at 60 min = V_∞

Table 2.1

reading	time, t / min	total volume of NaOH(aq) needed to neutralise total amount of $\text{H}^+(\text{aq})$ / cm^3	V_t / cm^3	$(V_\infty - V_t)$ / cm^3
1	1	12.60		
2	13	17.70		
3	20	19.90		
4	30	22.10		
5	40			
6	50	24.90		
7	60	25.90		

The student forgot to take reading 5.

(i) Complete Table 2.1. [2]

(ii) Identify the independent variable.

..... [1]

(iii) Identify **one** variable that needs to be controlled, apart from concentrations and volumes of solutions.

..... [1]

(iv) Reading 2 should have been taken at 10 minutes and **not** at 13 minutes.

State whether this result should have been included or not. Explain your answer.

.....
 [1]

- (v) Plot a graph on the grid in Fig. 2.1 to show the relationship between $(V_{\infty} - V_t)$ and time. Use a cross (×) to plot each data point. Draw a line of best fit.

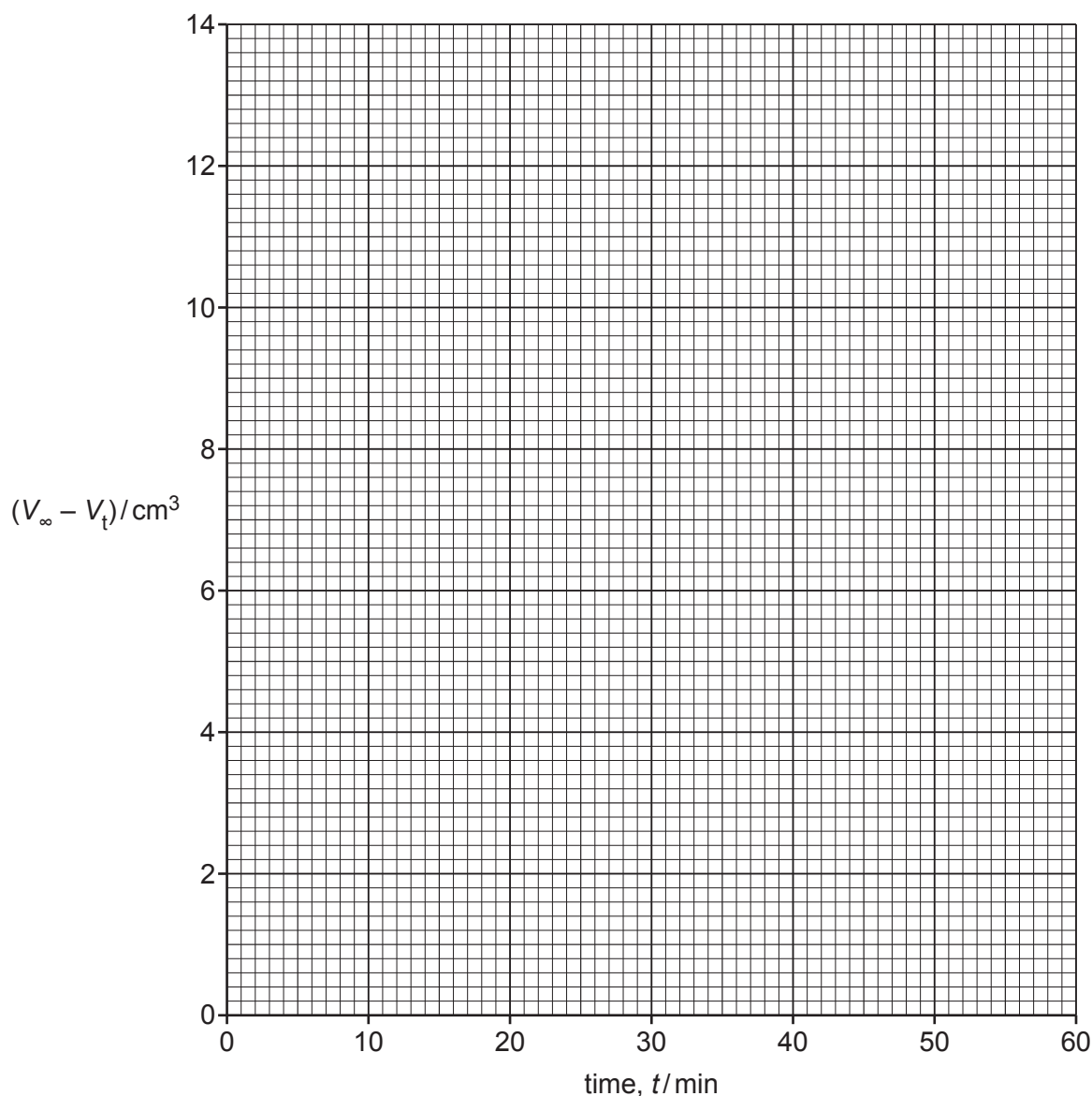


Fig. 2.1

[2]

- (vi) Reading 5 was **not** taken. Use the graph to predict the total volume of NaOH(aq) needed to neutralise the total amount of $H^+(aq)$ at 40 minutes.

volume of NaOH(aq) = [1]

- (vii) It is **not** possible to repeat the experiment.

State whether the data from the experiment is reliable. Justify your answer.

.....
 [1]

[Total: 12]

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Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

The Periodic Table of Elements

Group																											
1	2	Key														17	18										
		atomic number atomic symbol relative atomic mass												1 H hydrogen 1.0													
3	4																	2									
Li lithium 6.9	Be beryllium 9.0																	He helium 4.0									
11	12																	9	10								
Na sodium 23.0	Mg magnesium 24.3																	F fluorine 19.0	Ne neon 20.2								
																		8									
																		O oxygen 16.0									
																		7									
																		N nitrogen 14.0									
																		6									
																		C carbon 12.0									
																		5									
																		B boron 10.8									
																		13									
																		Al aluminium 27.0									
																		14									
																		Si silicon 28.1									
																		15									
																		P phosphorus 31.0									
																		16									
																		S sulfur 32.1									
																		17									
																		Cl chlorine 35.5									
																		18									
																		Ar argon 39.9									
19	20																	35	36								
K potassium 39.1	Ca calcium 40.1																	Br bromine 79.9	Kr krypton 83.8								
37	38																	53	54								
Rb rubidium 85.5	Sr strontium 87.6																	Sb antimony 121.8	I iodine 126.9								
55	56																	83	86								
Cs caesium 132.9	Ba barium 137.3																	84	Rn radon —								
87	88																	116	118								
Fr francium —	Ra radium —																	117	Og oganesson —								