Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER | CANDIDATE NUMBER

2288459680

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **February/March 2024**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS
- 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.

INFORMATION
- 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.

DC (DE/SG) 326111/5

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

The exact concentration of Cl^-(aq) in sea water can be determined by titration with aqueous silver ions, Ag^+(aq), using aqueous potassium chromate(VI), K_2CrO_4(aq), as an indicator.

When aqueous silver nitrate, $AgNO_3$(aq), is added to a sample of sea water, silver ions react with chloride ions to form a precipitate of silver chloride.

$$Ag^+(aq) \quad + \quad Cl^-(aq) \quad \rightarrow \quad AgCl(s)$$

When all of the Cl^-(aq) has reacted with Ag^+(aq), the presence of unreacted Ag^+(aq) is detected by chromate(VI) ions, CrO_4^{2-}(aq). A red precipitate of Ag_2CrO_4(s) is seen.

$$2Ag^+(aq) \quad + \quad CrO_4^{2-}(aq) \quad \rightarrow \quad Ag_2CrO_4(s)$$

The amount of Ag^+(aq) reacting with Cl^-(aq) in the sample of sea water can be calculated in order to determine the concentration of Cl^-(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 $AgNO_3$(s) into a 100 cm^3 glass beaker.

step 2 Use the sample of $AgNO_3$(s) in the glass beaker to prepare 250.0 cm^3 of $AgNO_3$(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 K_2CrO_4(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 $AgNO_3$(aq) in step 2, starting with the $AgNO_3$(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 K_2CrO_4(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 K_2CrO_4(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 = ... cm^3 [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, $HCOOCH_3$.

$$HCOOCH_3 + H_2O \rightleftharpoons HCOOH + CH_3OH$$

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 $H^+(aq)$ 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 $H^+(aq)$ 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 H^+(aq) ions from the catalyst, HCl(aq), and from the HCOOH produced in the reaction.

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

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

volume of NaOH(aq), in cm^3, used to neutralise H^+(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 H^+(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.

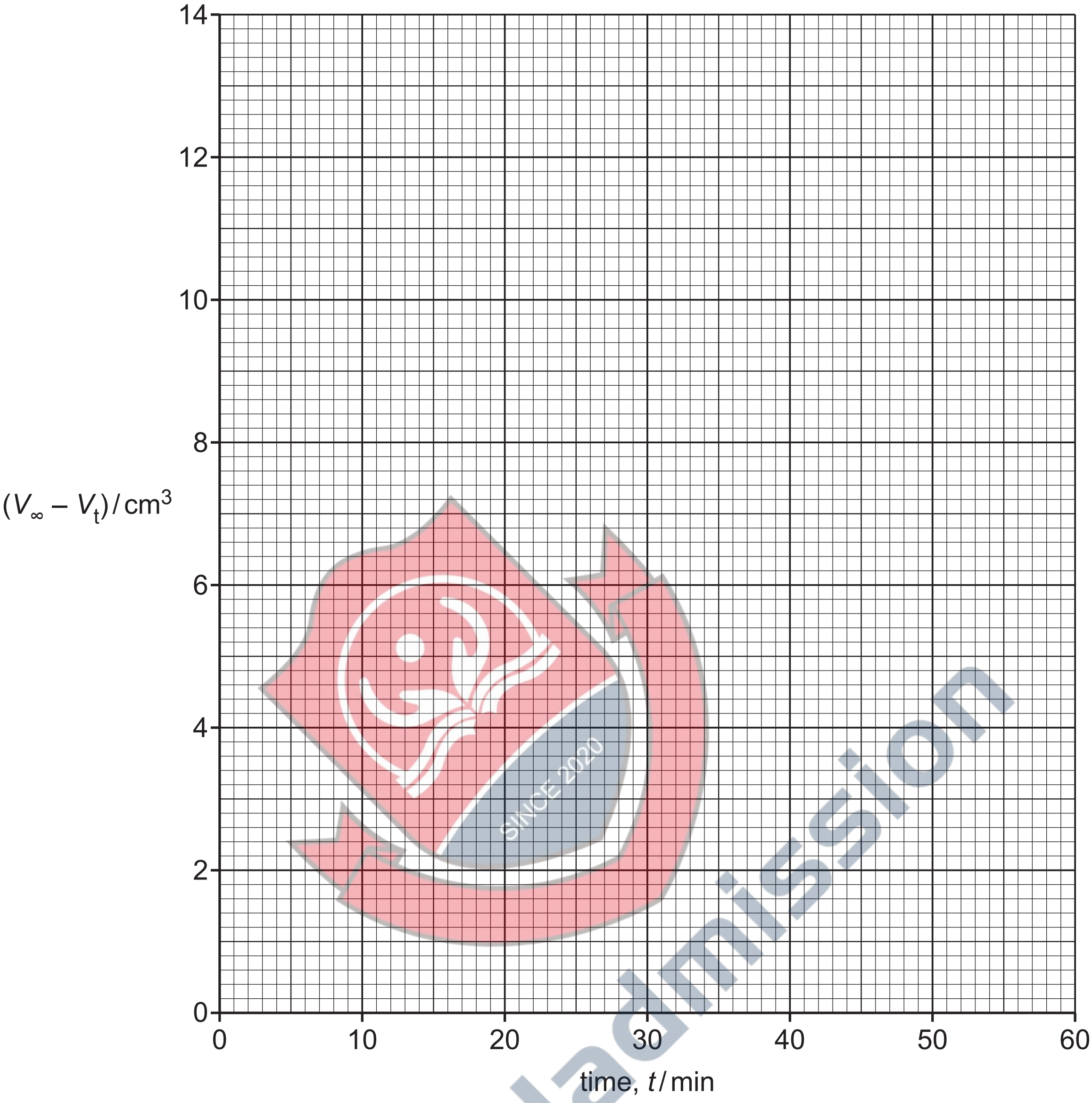

Fig. 2.1

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

The Periodic Table of Elements

Key

atomic number atomic symbol name relative atomic mass

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 A*l* aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 C*l* chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 T*l* thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 F*l* flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –