Past-paper walk-through

Reacting masses and volumes (of solutions and gases) ▪ 2.4

eXercise

Questions in this set

- 9701/11 N25 Q4 ▪ 1 mark
- 9701/14 N25 Q4 ▪ 1 mark
- 9701/31 N25 Q1 ▪ 15 marks
- 9701/31 N25 Q2 ▪ 10 marks
- 9701/34 N25 Q2 ▪ 14 marks
- 9701/51 N25 Q1 ▪ 16 marks
- 9701/52 N25 Q2 ▪ 13 marks
- 9701/34 J25 Q1 ▪ 14 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 4

9701/11 N25 ▪ Q4 ▪ 1 mark

4 Methane and steam react to produce hydrogen.

$$CH_4(g) + 2H_2O(g) \rightarrow CO_2(g) + 4H_2(g)$$

0.80 g of methane and 1.35 g of steam react. One of the reactants is used up.

Which volume of hydrogen, measured at room conditions, will be produced?

A $1.80\,dm^3$ **B** $3.60\,dm^3$ **C** $4.80\,dm^3$ **D** $7.20\,dm^3$

Solution 4

Answer: **B**

Why

- Moles: $CH_4 = 0.80/16.0 = 0.050$; $H_2O = 1.35/18.0 = 0.075$.
- 0.050 mol of methane would need 0.100 mol of steam, so the steam is the limiting reagent.
- 0.075 mol H_2O gives $0.075 \times 4/2 = 0.15$ mol H_2, which is $0.15 \times 24 = 3.6$ dm^3.

Question 4

9701/14 N25 ▪ Q4 ▪ 1 mark

4 A solution containing 4.4 g of an organic acid is exactly neutralised by 25.0 cm^3 of 2.0 mol dm^{-3} sodium hydroxide. The acid has one COOH group in each molecule.

What is the empirical formula of the acid?

A CH_2O **B** C_2H_4O **C** $C_3H_6O_3$ **D** $C_4H_8O_2$

Solution 4

Answer: **B**

Why

- NaOH: $0.0250 \times 2.0 = 0.050$ mol, and with one COOH group the acid is 0.050 mol too.
- $M_r = 4.4/0.050 = 88$, which matches the *molecular* formula $C_4H_8O_2$.
- But the question asks for the *empirical* formula, so divide through by 2: C_2H_4O.

Question 1

9701/31 N25 ▪ Q1 ▪ 15 marks

1 Hydrated ethanedioic acid is a diprotic acid with the formula $(COOH)_2 \cdot \mathbf{x}H_2O$ where **x** is an integer.

Ethanedioic acid reacts with manganate(VII) ions when heated.

$$5(COOH)_2(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

You will determine the value of **x** in $(COOH)_2 \cdot \mathbf{x}H_2O$ by titrating a solution containing ethanedioic acid with manganate(VII) ions.

- **FA 1** is $6.20\,g\,dm^{-3}$ aqueous ethanedioic acid, $(COOH)_2 \cdot \mathbf{x}H_2O$.
- **FA 2** is $0.0200\,mol\,dm^{-3}$ potassium manganate(VII), $KMnO_4$.
- **FA 3** is $1.0\,mol\,dm^{-3}$ sulfuric acid, H_2SO_4.

(a) **Method**

- Fill the burette with **FA 2**.
- Pipette $25.0\,cm^3$ of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately $20\,cm^3$ of **FA 3** to the conical flask.
- Place the conical flask on a tripod and gauze and heat carefully until the temperature of

Question 1

- Place the conical flask on a tripod and gauze and heat carefully until the temperature of the solution is approximately 70 °C.
- Remove the flame.
- Carefully lift the hot conical flask and place it on the white tile under the burette.
- Add **FA 2** drop-wise for the first 2–3 cm^3. Any initial pink colouring may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70 °C. If the brown colour disappears, continue the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- The end-point is reached when a permanent pale pink colour is formed.
- Perform a rough titration with **FA 2**. Record your burette readings in the space below.

Question 1

- Carry out as many titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record all your burette readings and the volume of **FA 2** added in each accurate titration.

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

Question 1

Question 1

(b) From your accurate titration results, calculate a suitable mean value to be used in your calculations.

Show clearly how you obtained this value.

Question 1

(c) Calculations

(i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the appropriate number of significant figures. [1]

(ii) Calculate the amount, in mol, of manganate(VII) ions, MnO_4^-, in the volume of **FA 2** calculated in **(b)**.

Question 1

(iii) Calculate the amount, in mol, of ethanedioic acid that reacts with the manganate(VII) ions in **(c)(ii)**.

Question 1

Hence calculate the concentration, in $mol\,dm^{-3}$, of ethanedioic acid in **FA 1**.

Question 1

[2]

(iv) Calculate the relative molecular mass, M_r, of the ethanedioic acid in **FA 1**.

Question 1

(v) Calculate the value of **x** in $(COOH)_2 \cdot \mathbf{x}H_2O$.

Show your working.

Question 1

(d) Explain why it is necessary to add **FA 3** in each titration.

Question 1

[Total: 15]

Solution 1

(a) Mark scheme

- I
- The following data are recorded:
- ▪
- two burette readings AND titre for the rough titration
- ▪
- initial and final burette readings for two (or more) accurate titrations
- 1
- II Titre values recorded for accurate titrations, AND

Solution 1

- Correct headings and units in the accurate titration table
- ▪
- initial / start AND (burette) reading / volume
- ▪
- final / end AND (burette) reading / volume
- ▪
- titre OR volume used/added/ OR FA 2 used/added
- ▪
- unit: / cm3 OR (cm3) OR in cm3 (for each heading) OR cm3 unit given for each volume recorded.

Solution 1

- 1
- III All accurate burette readings recorded to 0.05 cm3
- 1
- IV The final accurate titre recorded must be within 0.10 cm3 of any other accurate titre
- 1
- Accuracy (Q) marks
- Round burette readings to the nearest 0.05 cm3. Check and correct titre subtractions where necessary.
- Examiner selects the best mean titre, using the following hierarchy:
- ▪

Solution 1

- two (or more) accurate identical titres (ignoring any that are labelled ‘rough’), then
- ▪
- two (or more) accurate titres within 0.05 cm3, then
- ▪
- two(or more) accurate titres within 0.10 cm3, etc.
- Calculate the candidate’s mean titre value
- Calculate the supervisor’s mean titre value
- Calculate the difference ( ) between the candidate’s mean titre and the supervisor’s mean titre
- Award accuracy Q marks as follows:

Solution 1

- V
- Award if 0.50 cm3
- VI Award if 0.30 cm3
- VII Award if 0.20 cm3
- 3
- 9701/31
- October/November 2025

Solution 1

(b) Mark scheme

- Correctly calculates mean titre to 2 dp
- ▪
- Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm3.
- ▪
- Working/explanation must be shown OR ticks must be put next to the two (or more) accurate readings selected.
- ▪

Solution 1

- The mean should be quoted to 2 dp and be rounded to nearest 0.01 cm3. (e.g. 26.675 cm3 must be rounded to
- 26.68 cm3)
- 1

Solution 1

(c)(i)

Mark scheme

- All answers to (c)(ii), (c)(iii) and (c)(iv) to $3-4$ sf
- 1

Solution 1

(c)(ii)

Mark scheme

- Correctly calculates
- amount of manganate(VII) $= 0.02 \times$ volume in (b) / 1000 mol
- 1

Solution 1

(c)(iii)

Mark scheme

- Correctly uses **M1**
- Amount of ethanedioic acid = (c)(ii) × 5 / 2 mol **M2**
- Concentration of FA 1 = (c)(ii) × 5 / 2 × 1000 / 25 mol dm—3
- 2

Solution 1

(c)(iv)

Mark scheme

- Correctly uses
- Mr = 6.2(0) / (c)(iii)
- 1

Solution 1

(c)(v)

Mark scheme

- (Mr – 90) / 18
- AND
- correctly calculates answer as integer
- 1

Solution 1

(d)

Mark scheme

- $H+$ needed in the reaction / $H+$ used in / appears in the equation
- 1
- 9701/31
- October/November 2025

Question 2

9701/31 N25 ▪ Q2 ▪ 10 marks

2 Hydrated zinc sulfate has the formula $ZnSO_4$•**y**H_2O where **y** is an integer.

Hydrated zinc sulfate decomposes when heated, losing only its water of crystallisation and becoming anhydrous.

You will determine the value of **y** in $ZnSO_4$•**y**H_2O by heating the hydrated salt until it becomes anhydrous.

FA 4 is hydrated zinc sulfate, $ZnSO_4$•**y**H_2O.

(a) Method

- Weigh the crucible with its lid. Record the mass in the space for Results.
- Add between 3.20 g and 3.40 g of **FA 4** to the crucible.
- Weigh the crucible with its lid and **FA 4**. Record the mass.
- Place the crucible on the pipeclay triangle. Gently heat the crucible and contents for approximately 2 minutes with the lid on.
- Remove the lid. Heat the crucible and contents strongly for approximately 4 minutes.

Question 2

- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

You may wish to begin work on Question 3 while the crucible is cooling.

- Weigh the crucible with its lid and its contents. Record the mass.
- Remove the lid. Heat the crucible strongly for approximately 3 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.
- Weigh the crucible with its lid and its contents. Record the mass.
- Calculate the mass of **FA 4** used and the mass of residue obtained. Record the masses.

Results

I	
II	
III	
IV	

V	

[5]

(b) Calculations

(i) Calculate the amount, in mol, of anhydrous zinc sulfate residue formed in the decomposition of **FA 4**.

Question 2

Calculate the amount, in mol, of water of crystallisation lost.

Question 2

[2]

(ii) Calculate the value of **y** in the formula $ZnSO_4{\bullet}\mathbf{y}H_2O$.

Show your working.

Question 2

(c) A student suggests using this thermal decomposition method to investigate the number of moles of water of crystallisation in hydrated ethanedioic acid. The teacher says that this method is unsuitable.

Suggest why this method is unsuitable.

Question 2

[Total: 10]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write ‘no change’.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

Question 2

Question 2

If any solution is warmed, a boiling tube must be used. If a solid is heated, a hard-glass test-tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

Solution 2

(a) Mark scheme

- I
- Six correct headings with units in results space
- ▪
- (Mass) crucible + lid / g
- ▪
- (Mass) crucible + lid + FA 4 / g
- ▪
- (Mass) crucible + lid + residue / contents after first heading / g

Solution 2

- ▪
- (Mass) crucible + lid + residue after second heating / g
- ▪
- (Mass) FA 4 (used) / g
- ▪
- (Mass) residue / g
- Display of units: / g, (g), in g, in gram(me)s or in (column) heading covering all entries
- 1
- II

Solution 2

- Four readings in space provided
- ▪
- All four weighings recorded to same decimal places (either to two or to three)
- ▪
- Reading after 2nd heating within $+\ 0.02$ and $-\ 0.05$ of reading after 1st heating
- 1
- ll
- Correct subtractions
- ▪
- Correct calculations of mass FA 4 and residue

Solution 2

- AND
- ▪
- Mass of FA 4 is between 2.90 and 3.40 g.
- 1
- IV and V Accuracy
- Theoretical value $= 1.78$
- Calculate and record candidate's mass ratio
- $=$ mass FA 4 / mass of residue.
- Award IV if 1.51   candidate's mass ratio   2.05
- Award V if 1.60   candidates mass ratio   1.96

Solution 2

- 2
- 9701/31
- October/November 2025

Solution 2

(b)(i) Mark scheme

- Correctly uses **M1**
- Amount ZnSO4 = mass residue / 161.5 mol
- AND
- answer given to 2 – 4 sf
- Correctly calculates **M2**
- Amount H2O = mass water lost / 18 mol
- AND
- answer given to 2–4 sf

Solution 2

- 2

Solution 2

(b)(ii)

Mark scheme

- M1 y = moles H_2O / moles $ZnSO_4$ M2
- Expression evaluated and y correctly calculated quoted as integer
- 2

Solution 2

(c)

Mark scheme

- The (anhydrous ethanedioic) acid would decompose (on heating) / is flammable
- 1
- 9701/31
- October/November 2025
- FA 5 is $MgSO4 \cdot 7H2O$; FA 6 is KMnO4; FA 7 is acidified KMnO4(aq); FA 8 is MnSO4 or MnCl2; FA 9 is MnO2

Question 2

9701/34 N25 ▪ Q2 ▪ 14 marks

2 In this experiment you will determine the percentage by mass of a sodium halide impurity present in a sample of sodium hydrogencarbonate by titration.

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$$

FB 4 is an aqueous solution made by dissolving 17.20 g of the impure sodium hydrogencarbonate in each dm^3 of solution.
FB 5 is 0.200 $mol\,dm^{-3}$ hydrochloric acid, HCl.
FB 6 is methyl orange indicator.

(a) Method

- Fill the burette with **FB 5**.
- Pipette 25.0 cm^3 of **FB 4** into a conical flask.
- Add several drops of **FB 6** to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

Question 2

Question 2

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record all your burette readings and the volume of **FB 5** added in each accurate titration.

Keep FB 4 for use in Question 3.

Results

I	
II	
III	
IV	
V	
VI	
VII	

Question 2

Question 2

[7]

(b) From your accurate titration results, calculate a suitable mean value to be used in your calculations.
Show clearly how you obtained this value.

(c) Calculations

(i) Give your answers to **(c)(ii)** and **(c)(iii)** to an appropriate number of significant figures. [1]

(ii) Use your answer to **(b)** to calculate the amount, in mol, of hydrochloric acid in your mean titre.

Question 2

Hence determine the amount, in mol, of sodium hydrogencarbonate present in $25.0\,cm^3$ of **FB 4**.

Question 2

[1]

(iii) Calculate the mass of sodium hydrogencarbonate present in each dm^3 of solution.

Question 2

Hence calculate the percentage by mass of the sodium halide impurity in **FB 4**.
Show your working.

Question 2

[2]

(d) A student carries out the experiment in Question 1 using the impure sodium hydrogencarbonate dissolved to make **FB 4**.
State how this affects the value of ΔH_1 determined in **1(b)(iii)** compared to the value the student would get if pure sodium hydrogencarbonate were used.

Question 2

State what assumption you have made about the sodium halide impurity.

[2]

[Total: 14]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound

Question 2

must be given

Question 2

must be given.

If any solution is warmed, a boiling tube must be used. If any solid is heated a hard-glass test-tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

Solution 2

(a) Mark scheme

- I
- All the following data are recorded
- ▪
- two burette readings AND titre for the rough titration
- ▪
- initial and final burette readings for two (or more) accurate titrations
- 1
- II

Solution 2

- Titre values recorded for accurate titrations, AND Correct headings and units in the accurate titration table
- ▪
- initial / start AND (burette) reading / volume
- ▪
- final / end AND (burette) reading / volume
- ▪
- titre OR volume used / added / or FB 5 used / added
- ▪
- unit: / cm3 OR (cm3) OR in cm3 (for each heading) OR cm3 unit given for each volume recorded.

Solution 2

- 1
- III All accurate burette readings are recorded to the nearest 0.05 cm3.
- 1
- IV: The final accurate titre recorded is within 0.10 cm3 of any other accurate titre
- 1
- Accuracy (Q) marks
- Round burette readings to the nearest 0.05 cm3. Check and correct titre subtractions where necessary.
- Select the best mean titre, using the following hierarchy:
- ▪

Solution 2

- two (or more) accurate identical titres (ignoring any that are labelled ‘rough’), then
- ▪
- two (or more) accurate titres within 0.05 cm3, then
- ▪
- two (or more) accurate titres within 0.10 cm3, etc
- Calculate the candidate’s mean titre value.
- Calculate the supervisor’s mean titre value.
- Calculate the difference ( ) between the candidate’s mean titre and the supervisor’s mean titre.
- Award accuracy Q marks as follows:

Solution 2

- V award if 0.60 cm3
- VI award if 0.40 cm3
- VII award if 0.20 cm3
- 3
- 9701/34
- October/November 2025
- Question Answer

Solution 2

(b) Mark scheme

- Correctly calculates mean titre to 2 d.p.
- ▪
- Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm3.
- ▪
- Working / explanation must be shown OR ticks must be put next to the two (or more) accurate readings selected.
- ▪

Solution 2

- The mean should be quoted to 2 d.p. and rounded to nearest 0.01 cm3.
- 1

Solution 2

(c)(i)

Mark scheme

- Final answers to both parts (c)(ii) and (c)(iii) quoted to 3 or 4 sf.
- 1

Solution 2

(c)(ii)

Mark scheme

- Correctly calculates
- amount of HCl $= 0.2 \times$ (b) / 1000 (mol)
- AND gives same answer for amount of NaHCO3
- 1

Solution 2

(c)(iii) Mark scheme

- Correctly uses
- mass of NaHCO3 = (c)(ii) × 40 × 84(.0) (g)
- 1
- Correctly uses
- percentage by mass = [(17.20 – mass of NaHCO3) / 17.20] × 100
- OR percentage by mass = 100 – [(mass of NaHCO3 / 17.20) × 100]
- 1

Solution 2

(d)

Mark scheme

- M1: ($\Delta H1$) smaller / less positive (for impure $NaHCO3$)
- 1
- M2: Impurity does not react with the acid / FB 5/1 9701/34
- October/November 2025
- Question Answer
- FB 7 is $CuCO3(s)$; FB 8 is $FeSO4(aq)$

Question 1

9701/51 N25 ▪ Q1 ▪ 16 marks

1 The concentration of aqueous chloride ions can be found by titration with aqueous silver nitrate, $AgNO_3(aq)$.

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

The indicator used is aqueous potassium chromate(VI), $K_2CrO_4(aq)$.

As $AgNO_3(aq)$ is added to aqueous chloride ions, a white precipitate of $AgCl(s)$ is formed.

When all the chloride ions have reacted, further addition of $AgNO_3(aq)$ leads to the formation of a red precipitate of silver chromate(VI), $Ag_2CrO_4(s)$. The first appearance of the red precipitate shows the end-point of the titration.

A student carries out an experiment to determine the number of molecules of water of crystallisation, *x*, in hydrated barium chloride, $BaCl_2\text{•}xH_2O(s)$.

(a) The student makes $250.0\,cm^3$ of $0.0500\,mol\,dm^{-3}$ $AgNO_3(aq)$ to use for the titration.

Question 1

(i) Calculate the mass of solid silver nitrate, $AgNO_3(s)$, needed to make $250.0\,cm^3$ of $0.0500\,mol\,dm^{-3}$ $AgNO_3(aq)$.

Give your answer to **two** decimal places.

Question 1

(ii) Describe how the student should make 250.0 cm^3 of 0.0500 mol dm^{-3} $AgNO_3(aq)$ starting from the mass of $AgNO_3(s)$ calculated in **(a)(i)** in a 50 cm^3 beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

Question 1

(b) The student uses the following method.

step 1 Dissolve 1.58 g of $BaCl_2 \cdot xH_2O(s)$ to form 250 cm^3 of aqueous solution. Label this solution **A**.

step 2 Transfer 20.0 cm^3 of solution **A** into a conical flask.

step 3 Add aqueous sodium sulfate, $Na_2SO_4(aq)$, to the flask and swirl the mixture to remove barium ions from the solution.

step 4 Add 2–3 drops of $K_2CrO_4(aq)$ indicator to the flask.

step 5 Titrate the contents of the flask against 0.0500 $mol\,dm^{-3}$ $AgNO_3(aq)$.

step 6 Repeat steps 2 to 5 to collect sufficient data for analysis.

(i) Suggest a suitable piece of apparatus for transferring 20.0 cm^3 of solution **A** in step 2.

Question 1

(ii) Suggest why barium ions are removed in step 3 before performing the titration.

Question 1

(iii) Suggest why chemically resistant gloves should be worn to carry out step 4.

Question 1

(c) The student's results are shown in Table 1.1.

Table 1.1

	rough titration	titration 1	titration 2	titration 3
burette reading (final) / cm^3	20.10	40.55	20.75	20.90
burette reading (initial) / cm^3	0.00	20.25	0.05	0.30
titre / cm^3	20.10	20.30	20.70	20.60

The student uses the titres from titrations 2 and 3 shown in Table 1.1 to calculate a mean titre value of 20.65 cm^3.

(i) Explain why only these two values are used.

Question 1

Question 1

(ii) Calculate the percentage error in the titre volume for titration 3.
Show your working.

Question 1

(d) The equation for the reaction of silver nitrate with barium chloride is shown.

$$2AgNO_3(aq) + BaCl_2(aq) \rightarrow Ba(NO_3)_2(aq) + 2AgCl(s)$$

(i) Calculate the amount, in mol, of $AgNO_3$(aq) in the mean titre of 20.65 cm^3.

Question 1

(ii) Calculate the amount, in mol, of $BaCl_2$(aq) in 250 cm^3 of solution **A**.

Question 1

(iii) Calculate the value of *x* in the formula $BaCl_2 \cdot xH_2O$.

Question 1

(e) Another student uses a different experimental method to check the value of *x* obtained by the method described in **(b)**.

Give a **brief** description of another method, not involving titration, that could be used to determine the value of *x* in the formula $BaCl_2{\bullet}xH_2O(s)$. Write your answer using a series of numbered steps.

Your plan should include details of the following:

- the apparatus and method you would use
- the measurements you would make.

You are provided with standard laboratory apparatus.

Question 1

[Total: 16]

Solution 1

(a)(i)

Mark scheme

- 2.12 g
- 1

Solution 1

(a)(ii) Mark scheme

- M1 add a (small) volume of (distilled) water (to the small beaker)
- AND
- dissolve the solid / $AgNO_3$ (s)
- Transfer the solution and washings (using a funnel)
- AND
- into a 250 cm^3 volumetric flask. M3
- Make up to the (calibration) mark / line with distilled water.
- AND

Solution 1

- then invert the (stoppered) flask (several times)
- 3

Solution 1

(b)(i)

Mark scheme

- (20(.0) cm3) pipette.
- 1

(b)(ii)

Mark scheme

- barium (ions) could react with chromate (ions).
- 1

Solution 1

(b)(iii)

Mark scheme

- Potassium chromate(VI) / K2CrO4(aq) is an irritant / corrosive
- 1

Solution 1

(c)(i)

Mark scheme

- They are (the only ones that are) concordant.
- 1

Solution 1

(c)(ii) Mark scheme

- 2
- 0.05 100
- 20.60
- $\times$
- $\times$
- $= 0.48(54\%)$
- Correct working must be shown.
- 1

Solution 1

(d)(i)

Mark scheme

- $20.65 \times 0.05 \,/\, 1000 = 0.00103(25)$
- 1

Solution 1

(d)(ii)

Mark scheme

- $=$ ((d)(i) / 2) *(250 / 20)
- $=$ (d)(i) $\times$ 6.25
- 1
- 9701/51
- October/November 2025

Solution 1

(d)(iii)

Mark scheme

- M1 Mr $= 1.58$ / (d)(ii) M2
- x$=$ (M1 – 208.3) / 18
- AND
- x must be an integer.
- Some working must be shown.
- 2

Solution 1

(e) Mark scheme

- Heat to drive off water of crystallisation. M1
- Apparatus
- 1
- Bunsen burner.
- 2
- Crucible (supported by pipeclay triangle) M2
- Measurements
- 1

Solution 1

- Measure mass of crucible (+ lid) (empty).
- 2
- Measure mass crucible (+ lid) + solid before heating
- 3
- Measure mass of crucible (+ lid) + residue (after heating.) M3
- Key step in method
- ▪
- Description of heat to constant mass.
- OR
- Produce a suitable precipitate using a viable reaction. M1

Solution 1

- Apparatus and method
- ▪
- Chooses suitable reagent.
- ▪
- Filter the precipitate.
- ▪
- Wash and (allow to) dry M2
- Measurements
- ▪
- Measure mass of hydrated barium chloride used.

Solution 1

- ▪
- Measure mass of precipitate. M3
- Key step in method
- ▪
- Description of dry to constant mass.
- 3
- 9701/51
- October/November 2025

Question 2

9701/52 N25 ▪ Q2 ▪ 13 marks

2 A student carries out an experiment to determine the concentration of aqueous sulfate ions, $SO_4^{2-}(aq)$, in a sample of lake water.

(a) The student uses the following method.

step 1 Transfer $25.00\,cm^3$ of the lake water sample to a beaker and record its conductivity as shown in Fig. 2.1.

step 2 Add $5.00\,cm^3$ of $0.100\,mol\,dm^{-3}$ aqueous barium hydroxide, $Ba(OH)_2(aq)$, to the beaker.

step 3 Stir the mixture and record the conductivity of the contents of the beaker as shown in Fig. 2.1.

step 4 Repeat steps 2 and 3 until a total of $40.00\,cm^3$ of $0.100\,mol\,dm^{-3}$ $Ba(OH)_2(aq)$ has been added to the beaker.

conductivity meter

Question 2

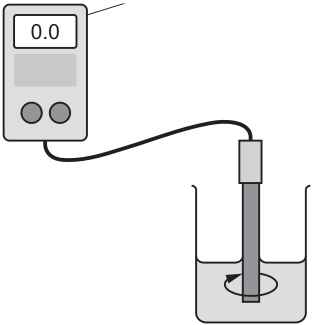


Fig. 2.1

(i) Suggest a suitable piece of apparatus to transfer 25.00 cm^3 of the lake water sample to the beaker in step 1.

Question 2

(ii) $0.100\,\text{mol}\,\text{dm}^{-3}$ $Ba(OH)_2(aq)$ is an irritant to skin and eyes. Other than wearing safety goggles, state **one** safety precaution that the student should take when conducting this experiment.

Question 2

(b) The student's results are given in Table 2.1.

A correction can be applied to the conductivity values to take into account dilution of the solution as its volume increases using the following equation.

Question 2

25.00

Table 2.1

reading number	volume of 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ added to beaker / cm^3	total volume in beaker / cm^3	measured conductivity / µS cm^{-1}	corrected conductivity / µS cm^{-1}
1	0.00	25.00	37 000	37 000
2	5.00		23 000	27 600
3	10.00		12 000	16 800
4	15.00		2 300	3 680

Question 2

Question 2

5	20.00		5 000	
6	25.00		12 000	
7	30.00		18 000	
8	35.00		21 000	
9	40.00		24 500	

(i) Complete Table 2.1. [2]

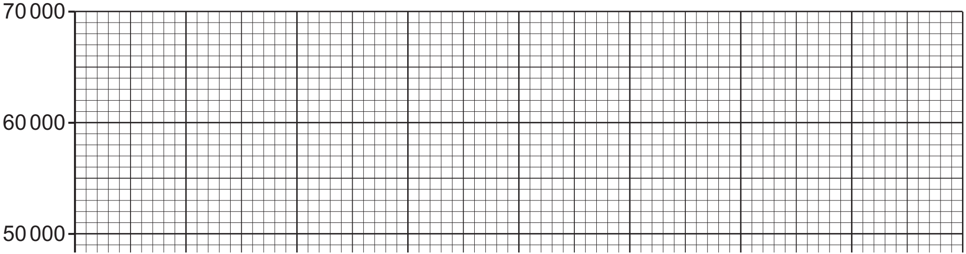
(ii) Identify the independent variable in this experiment.

Question 2

(c) Plot a graph on the grid in Fig. 2.2 to show the relationship between corrected conductivity and volume of 0.100 mol dm^{-3} $Ba(OH)_2$ added to beaker.

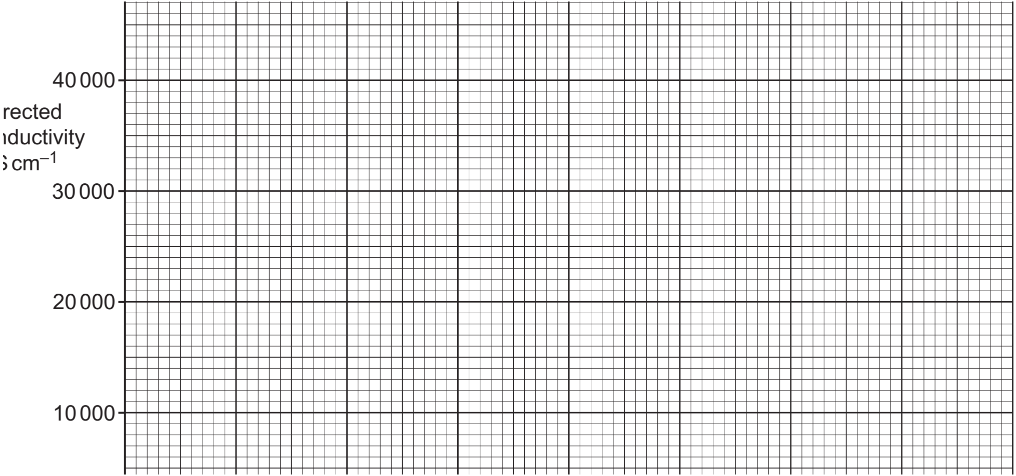
Use a cross (×) to plot each data point.

Draw a line of best fit using readings 1 to 4 and another line of best fit using readings 5 to 9. Extend the lines so that they intersect.



Question 2

Question 2



Question 2

Question 2

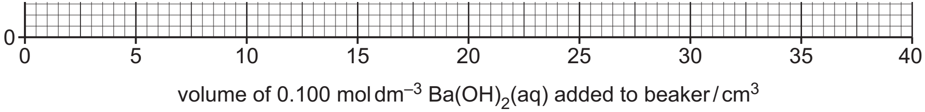


Fig. 2.2

[2]

(d) The point on the graph where the two lines intersect indicates the volume of 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ required to react exactly with the $SO_4^{2-}(aq)$ present in 25.00 cm^3 of lake water being tested.

(i) Use the graph in Fig. 2.2 to determine the volume of 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ required to react exactly with $SO_4^{2-}(aq)$ in the lake water sample.

Question 2

(ii) The equation for the reaction taking place in the beaker is shown.

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

Use your answer in **(d)(i)** to calculate the concentration of $SO_4^{2-}(aq)$ in the lake water sample.

(e) The concentration of $SO_4^{2-}(aq)$ in a sample of water can also be determined by measuring the mass of precipitate produced when excess $Ba(OH)_2(aq)$ is added to the sample.

The student suggests the following method.

step 1 Place $25.0\,cm^3$ of the water sample in a conical flask.

step 2 Add excess $0.100\,mol\,dm^{-3}$ $Ba(OH)_2(aq)$ to the flask.

step 3 Filter the contents of the flask.

step 4 Dry the residue in a warm oven.

step 5 Measure the mass of residue.

(i) Draw a labelled diagram to describe the arrangement of apparatus that would be needed to complete step 3.

Question 2

[1]

(ii) Suggest a step that the student should add between steps 3 and 4 to improve this method.

Question 2

(iii) Describe what the student can do to ensure that the residue weighed in step 5 is completely dry.

Question 2

(iv) The mass of residue is used to calculate the concentration of SO_4^{2-}(aq).

Suggest the effect, if any, on the concentration of SO_4^{2-}(aq) that is calculated if the residue is **not** completely dried in step 4.

Explain your answer.

Question 2

[1]

[Total: 13]

Important values, constants and standards

molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Faraday constant	$F = 9.65 \times 10^{4}\,\mathrm{C\,mol^{-1}}$
Avogadro constant	$L = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
electronic charge	$e = -1.60 \times 10^{-19}\,\mathrm{C}$
molar volume of gas	$V_m = 22.4\,\mathrm{dm^3\,mol^{-1}}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\mathrm{dm^3\,mol^{-1}}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\mathrm{mol^2\,dm^{-6}}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\mathrm{kJ\,kg^{-1}\,K^{-1}}$ ($4.18\,\mathrm{J\,g^{-1}\,K^{-1}}$)

Question 2

12	13	14	15	16	17	18
						2 He helium 4.0
	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
	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
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
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
80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

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
98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

Question 2

The Periodic Table of Elements

Group

Key	
ic number	1
c symbol	H
name	hydrogen
atomic mass	1.0

5	6	7	8	9	10	11
23 V nadium 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
41 Nb iobium 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
73 Ta ntalum 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
105 Db ubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –

59 Pr eodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9
91 Pa tactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –

Question 2

1	2	3	4
3 Li lithium 6.9	4 Be beryllium 9.0		
11 Na sodium 23.0	12 Mg magnesium 24.3		
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1
actinoids	89 Ac actinium –	90 Th thorium 232.0

Solution 2

(a)(i)

Mark scheme

- (25.0 cm3) volumetric pipette
- 1

Solution 2

(a)(ii)

Mark scheme

- (wear) chemically resistant gloves
- 1
- 9701/52
- October/November 2025

Solution 2

(b)(i) Mark scheme

- Total volume
- in beaker /
- cm3
- Corrected
- conductivity
- / S cm–1
- 25.00
- 37000

Solution 2

- 30.00
- 27600
- 35.00
- 16800
- 40.00
- 3680
- 45.00
- 9000
- 50.00
- 24000

Solution 2

- 55.00
- 39600
- 60.00
- 50400
- 65.00
- 63700 M1
- Total volume in beaker values M2
- Corrected conductivity values
- 2

Solution 2

(b)(ii)

Mark scheme

- volume of 0.100 mol dm–3 Ba(OH)2(aq) added to beaker
- 1

Solution 2

(c) Mark scheme

- M1: all points 1–4 and 5–9 plotted correctly
- M2: two straight lines of best fit line drawn going through most points.
- lines must intersect.
- Place M2 tick in 'V' of graph
- Place M1 tick or cross on left hand side of grid
- Place cross (or highlight) against mis-plot
- 2
- 9701/52

Solution 2

- October/November 2025

Solution 2

(d)(i)

Mark scheme

- intersection point volume (read from within grid)
- 1

Solution 2

(d)(ii)

Mark scheme

- nSO42– =0.100 × ans (d)(i) / 1000 = mol

SO42–(aq) = [0.100 × (d)(i) / 1000] / 0.025

- 1

Solution 2

(e)(i)

Mark scheme

- diagram showing labelled filter paper in a labelled (filter) funnel
- 1

(e)(ii)

Mark scheme

- wash the residue with distilled water
- 1

Solution 2

(e)(iii)

Mark scheme

- heat to constant mass
- 1

Solution 2

(e)(iv)

Mark scheme

- higher value
- and
- (water would cause) (measured) mass / amount (of residue) would be greater
- 1

Question 1

9701/34 J25 ▪ Q1 ▪ 14 marks

Iron is an element that is essential in the human diet. Some people need to take iron supplement tablets to ensure an adequate intake of iron.
You will investigate the mass of iron in an iron supplement tablet by titrating a solution with potassium manganate(VII).

$$\mathrm{Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^{-}}$$

$$\mathrm{MnO_4^{-}(aq) + 8H^{+}(aq) + 5e^{-} \rightarrow Mn^{2+}(aq) + 4H_2O(l)}$$

FB 1 is an aqueous solution of iron supplement tablets made by dissolving 14 tablets in $1.00\,\mathrm{dm^3}$ of solution. The iron in each tablet is iron(II) sulfate, $FeSO_4 \cdot 7H_2O$. **FB 2** is $0.0100\,\mathrm{mol\,dm^{-3}}$ acidified aqueous potassium manganate(VII), $KMnO_4$. **FB 3** is dilute sulfuric acid, H_2SO_4.

Question 1

(a) Method

- Fill a burette with **FB 2**.
- Pipette 25.0cm^3 of **FB 1** into a conical flask.
- Use the 25cm^3 measuring cylinder to add 10.0cm^3 of **FB 3** to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is ___ cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record, in a suitable form in the space below, all your burette readings and the volume of **FB 2** added in each accurate titration.

Question 1

Rinse the burette with distilled water and leave to drain while you continue Question 1.

Results **[7]**

Question 1

I	
II	
III	
IV	
V	
VI	
VII	

[7]

Question 1

9701/34 J25 ▪ Q1 ▪ 14 marks

Iron is an element that is essential in the human diet. Some people need to take iron supplement tablets to ensure an adequate intake of iron.
You will investigate the mass of iron in an iron supplement tablet by titrating a solution with potassium manganate(VII).

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$$

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

FB 1 is an aqueous solution of iron supplement tablets made by dissolving 14 tablets in $1.00\,dm^3$ of solution. The iron in each tablet is iron(II) sulfate, $FeSO_4 \cdot 7H_2O$. **FB 2** is $0.0100\,mol\,dm^{-3}$ acidified aqueous potassium manganate(VII), $KMnO_4$. **FB 3** is dilute sulfuric acid, H_2SO_4.

Question 1

(b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm^3 of **FB 1** required cm^3 of **FB 2**. **[1]**

Question 1

9701/34 J25 ▪ Q1 ▪ 14 marks

Iron is an element that is essential in the human diet. Some people need to take iron supplement tablets to ensure an adequate intake of iron.
You will investigate the mass of iron in an iron supplement tablet by titrating a solution with potassium manganate(VII).

$$\mathrm{Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-}$$

$$\mathrm{MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)}$$

FB 1 is an aqueous solution of iron supplement tablets made by dissolving 14 tablets in $1.00\,\mathrm{dm^3}$ of solution. The iron in each tablet is iron(II) sulfate, $FeSO_4 \cdot 7H_2O$. **FB 2** is $0.0100\,\mathrm{mol\,dm^{-3}}$ acidified aqueous potassium manganate(VII), $KMnO_4$. **FB 3** is dilute sulfuric acid, H_2SO_4.

Question 1

(c)(i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to an appropriate number of significant figures. **[1]**

(c)(ii) Calculate the amount, in mol, of manganate(VII) ions in the volume of **FB 2** in **(b)**. **[1]**

(c)(iii) Use your answer to **(c)(ii)** and the equations at the start of the question to calculate the concentration, in mol dm^{-3}, of iron(II) ions in **FB 1**. **[1]**

(c)(iv) Use your answer to **(c)(iii)** to calculate the concentration, in g dm^{-3}, of iron(II) ions in **FB 1**. **[1]**

(c)(v) The manufacturer of the iron supplement tablets used to make **FB 1** claims that each tablet contains a minimum of 150 mg of Fe^{2+}.

Use your answer to **(c)(iv)** and the information given about **FB 1** to determine whether this claim is correct. Show your working. **[1]**

Question 1

9701/34 J25 ▪ Q1 ▪ 14 marks

Iron is an element that is essential in the human diet. Some people need to take iron supplement tablets to ensure an adequate intake of iron.
You will investigate the mass of iron in an iron supplement tablet by titrating a solution with potassium manganate(VII).

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$$

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

FB 1 is an aqueous solution of iron supplement tablets made by dissolving 14 tablets in $1.00\,dm^3$ of solution. The iron in each tablet is iron(II) sulfate, $FeSO_4 \cdot 7H_2O$. **FB 2** is $0.0100\,mol\,dm^{-3}$ acidified aqueous potassium manganate(VII), $KMnO_4$. **FB 3** is dilute sulfuric acid, H_2SO_4.

Question 1

(d) A student used all the **FB 3** and suggests that dilute hydrochloric acid would be a suitable replacement. Suggest whether the student is correct or not. Explain your answer. **[1]**

Solution 1

(a) Mark scheme

I All the following data recorded.

- two burette readings **AND** titre for the rough titration
- initial and final readings for **two** (or more) accurate titrations

II Titre values recorded for accurate titrations, **AND** correct headings and units in the accurate titration table

- initial / start **AND** (burette) reading / volume
- final / end **AND** (burette) reading / volume
- titre **OR** volume used / added **OR** FB 2 used / added
- unit: / cm^3 **OR** (cm^3) **OR** in cm^3 (for each heading) **OR** cm^3 unit given for each volume recorded.

Solution 1

III All accurate burette readings recorded to 0.05 cm^3. **IV** The final accurate titre recorded must be within 0.10 cm^3 of any other accurate titre.

Accuracy (Q) marks Round burette readings to the nearest 0.05 cm^3. Check and correct titre subtractions where necessary. Select the best mean titre, using the following hierarchy:

- two (or more) accurate identical titres (ignoring any that are labelled "rough"), *then*
- two (or more) accurate titres within 0.05 cm^3, *then*
- two (or more) accurate titres within 0.10 cm^3, *etc.*

Solution 1

Calculate the Supervisor's mean titre to two decimal places. Calculate the Candidate's mean titre to two decimal places. Calculate the difference (δ) between the Supervisor's and Candidate's mean titre.

Award accuracy Q marks as follows: **V** award if $\delta \leq 0.50$ cm^3 **VI** award if $\delta \leq 0.30$ cm^3 **VII** award if $\delta \leq 0.20$ cm^3

Solution 1

(b)

Mark scheme

Correct calculation of the mean titre

- Candidate must take the average of two (or more) titres that are within a total spread of not more than 0.20 cm^3.
- Working/explanation must be shown OR ticks must be put next to the two (or more) accurate readings selected.
- The mean should be quoted to 2 d.p. and be rounded to nearest 0.01 cm^3 (e.g. 26.675 cm^3 must be rounded to 26.68 cm^3).

Solution 1

(c)(i)

Mark scheme

- Final answers for (c)(ii), (c)(iii) and (c)(iv) to 3 or 4 significant figures.

(c)(ii)

Mark scheme

- Correctly calculates
- amount of manganate(VII) $= 0.01 \times \frac{\text{volume in (b)}}{1000}$ mol

Solution 1

(c)(iii)

Mark scheme

- Correctly uses
- amount of Fe^{2+} reacting with FB 2 $=$ (c)(ii) $\times$ 5 mol
- AND concentration of Fe^{2+} $=$ ((c)(ii) $\times$ 5) $\times$ 40 mol dm^{-3}

Solution 1

(c)(iv)

Mark scheme

- Correctly uses
- concentration of Fe^{2+} = (c)(iii) $\times$ 55.8 g dm^{-3}

Solution 1

(c)(v)

Mark scheme

- Conclusion
- yes / correct (because)
- AND (c)(iv) $\times$ 1000 / 14 (> 150 claimed as present in tablet)

Solution 1

(d)

Mark scheme

- no because chloride (ions) are oxidised by manganate(VII) / $KMnO_4$.
- OR no because hydrochloric acid is monoprotic AND might not produce enough H^+.
- OR yes because hydrochloric acid is a strong acid.