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9701/54

May/June 2026

**1 hour 15 minutes**

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. Do **not** use correction fluid or tape.
- 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.

- 1 A student uses two different methods to determine the value of integer  $x$  in hydrated sodium carbonate crystals,  $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}(\text{s})$ .

### Method 1

The student uses the following procedure.

- step 1** Weigh an empty crucible.
- step 2** Add approximately 5 g of  $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}(\text{s})$  to the crucible.
- step 3** Weigh the crucible and contents.
- step 4** Heat the crucible and contents for 5 minutes.
- step 5** Allow the crucible to cool. Weigh the crucible and residue.

- (a) Suggest what the student should do to ensure all the water is removed from the hydrated salt.

..... [1]

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

**Table 1.1**

|                                                                            | mass / g |
|----------------------------------------------------------------------------|----------|
| mass of empty crucible                                                     | 17.68    |
| mass of crucible + contents                                                | 22.57    |
| mass of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}(\text{s})$ added |          |
| mass of crucible + residue                                                 | 19.74    |
| mass of residue                                                            |          |

- (i) Complete Table 1.1. Hence, calculate the mass, in g, of water lost.

mass of water lost = ..... g  
[1]

- (ii) Using the same apparatus, suggest a modification that the student could make to the method to reduce the percentage error in the measurement of the mass of water lost.

.....  
..... [1]

- (c) Use the student's results for Method 1 to calculate the value of  $x$  in  $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}(\text{s})$ .

Show your working. Give your answer to the nearest whole number.

$x =$  ..... [2]

(d) **Method 2**

The student uses the following procedure.

**step 1** Prepare  $250.0 \text{ cm}^3$  of solution **A** containing  $0.365 \text{ g}$  of  $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}(\text{s})$ .

**step 2** Fill a burette with  $0.0100 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}(\text{aq})$ .

**step 3** Use a pipette to transfer  $25.0 \text{ cm}^3$  of solution **A** to a conical flask.

**step 4** Titrate the contents of the conical flask against  $0.0100 \text{ mol dm}^{-3}$   $\text{HCl}(\text{aq})$  using methyl orange indicator.

Repeat steps 3 and 4 as many times as necessary.

The equation for the reaction is shown.



- (i) Describe how the student should make  $250.0 \text{ cm}^3$  of solution **A**, starting from  $0.365 \text{ g}$  of  $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}(\text{s})$  in a  $50 \text{ cm}^3$  beaker.

Give the name and capacity of any apparatus used.

Write your answer using a series of numbered steps.

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

- (ii) Identify the substance that should be used to rinse the burette before carrying out step 2 in Method 2.

..... [1]

- (e) The student's titration results are shown in Table 1.2.

Table 1.2

|                                         | rough titration | titration 1 | titration 2 | titration 3 |
|-----------------------------------------|-----------------|-------------|-------------|-------------|
| final burette reading/cm <sup>3</sup>   | 25.50           | 25.25       | 30.45       | 25.40       |
| initial burette reading/cm <sup>3</sup> | 0.10            | 0.00        | 5.45        | 0.25        |
| titre/cm <sup>3</sup>                   | 25.40           | 25.25       | 25.00       | 25.15       |

- (i) The student calculates the mean titre as 25.20 cm<sup>3</sup>.

Explain why this is a suitable value for the mean titre.

.....  
 ..... [1]

- (ii) Use the mean titre value of 25.20 cm<sup>3</sup> to calculate the value of  $x$  in hydrated sodium carbonate, Na<sub>2</sub>CO<sub>3</sub>• $x$ H<sub>2</sub>O(s).

Show your working. Give your answer to the nearest whole number.

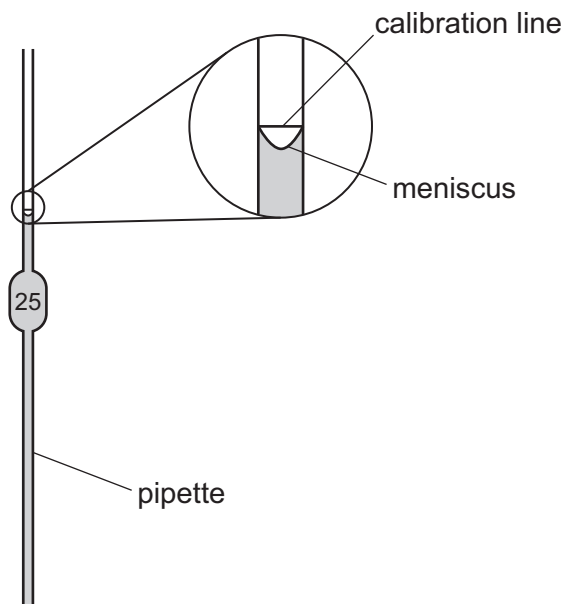
$x$  = ..... [4]

- (iii) Calculate the percentage error in the titre for titration 3.

Show your working.

percentage error = ..... % [1]

- (f) Another student consistently performed step 3 in Method 2 incorrectly. Figure 1.1 shows the level of solution **A** in the pipette during each transfer to the conical flask.



**Figure 1.1**

Suggest the effect this has on the value of **x** determined by the student.

Explain your answer.

effect on value of **x** .....

explanation .....

.....

[1]

[Total: 16]

- 2 A student makes ammonia gas,  $\text{NH}_3(\text{g})$ , in the laboratory by heating a mixture of solid ammonium chloride,  $\text{NH}_4\text{Cl}(\text{s})$ , and solid calcium hydroxide,  $\text{Ca}(\text{OH})_2(\text{s})$ .



The student uses the apparatus shown in Figure 2.1 to collect a sample of  $\text{NH}_3(\text{g})$ .

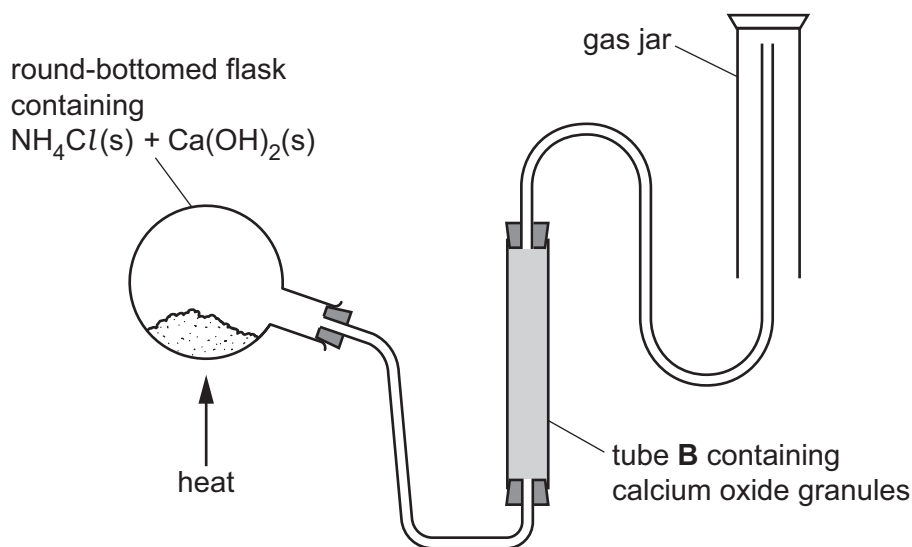


Figure 2.1

- (a) (i) The student uses 5.00 g of  $\text{NH}_4\text{Cl}(\text{s})$ . Calculate the minimum mass, in g, of  $\text{Ca}(\text{OH})_2(\text{s})$  that should be added to the round-bottomed flask to react fully with 5.00 g of  $\text{NH}_4\text{Cl}(\text{s})$ .

Give your answer to **three** significant figures.

mass of  $\text{Ca}(\text{OH})_2(\text{s}) = \dots\dots\dots \text{g}$  [1]

- (ii) Suggest why the student carries out this experiment in a fume hood.

$\dots\dots\dots$  [1]

- (iii) Tube **B** contains calcium oxide granules.

Suggest why  $\text{NH}_3(\text{g})$  is passed through tube **B** before collection.

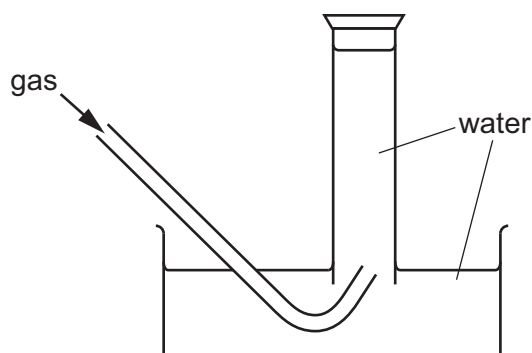
..... [1]

- (iv)  $\text{NH}_3(\text{g})$  is collected in an inverted gas jar as shown in Figure 2.1.

Suggest why it is possible to collect  $\text{NH}_3(\text{g})$  in this way.

..... [1]

- (b) Figure 2.2 shows an alternative method of collecting a gas.

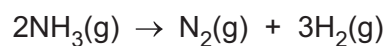


**Figure 2.2**

Suggest why the apparatus shown in Figure 2.2 is **not** suitable to collect the  $\text{NH}_3(\text{g})$  produced.

..... [1]

(c) The student investigates the decomposition of  $\text{NH}_3(\text{g})$  in the presence of a catalyst.



The student measures the concentration of  $\text{NH}_3(\text{g})$  as the reaction proceeds.

Two catalysts, tungsten and nickel-loaded silica, are compared.

The student's results using tungsten are plotted on the grid in Figure 2.3. The line of best fit is labelled 'tungsten'.

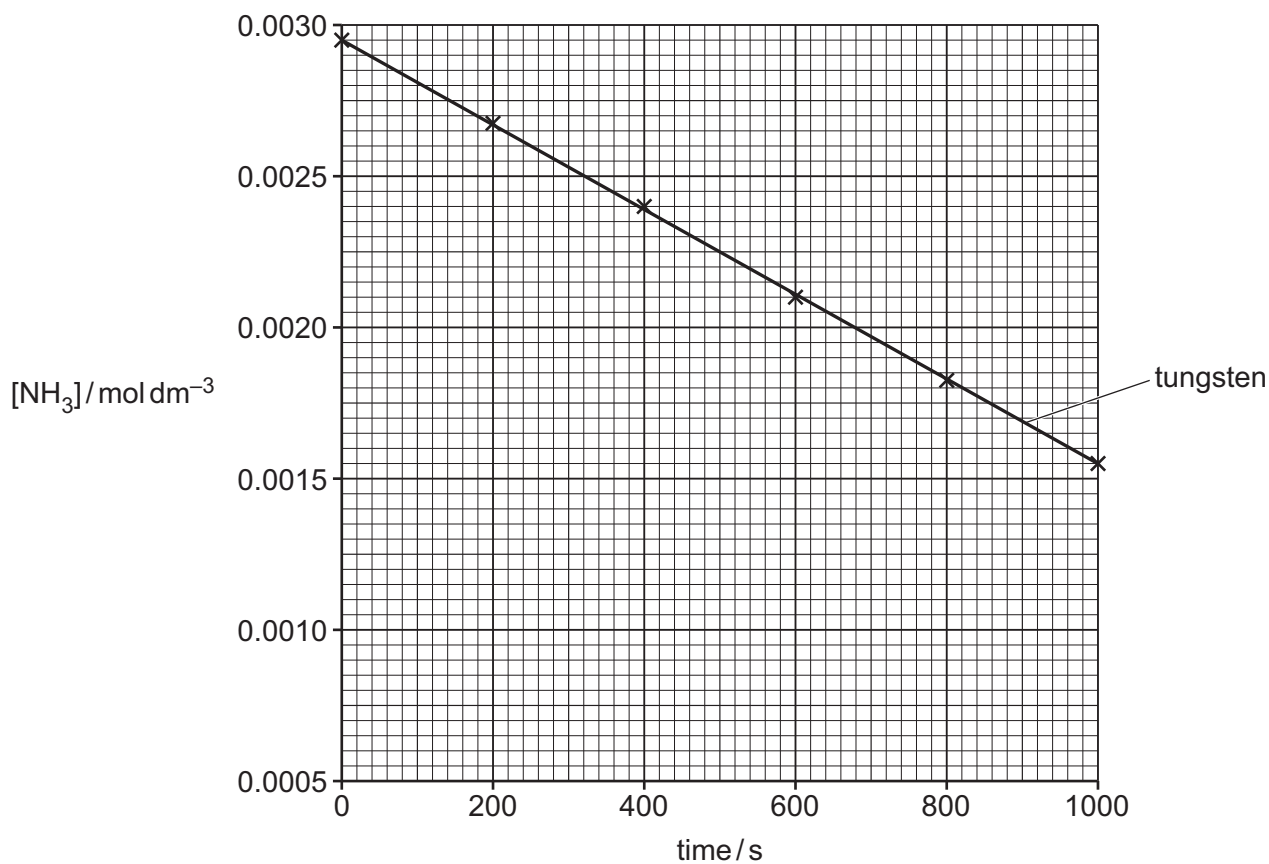


Figure 2.3

The student repeats the experiment using nickel-loaded silica as the catalyst in place of tungsten.

The student's results using nickel-loaded silica are shown in Table 2.1.

**Table 2.1**

| time/s | $[\text{NH}_3]/\text{mol dm}^{-3}$ |
|--------|------------------------------------|
| 0      | $2.95 \times 10^{-3}$              |
| 200    | $2.23 \times 10^{-3}$              |
| 400    | $1.68 \times 10^{-3}$              |
| 600    | $1.27 \times 10^{-3}$              |
| 800    | $9.63 \times 10^{-4}$              |
| 1000   | $7.27 \times 10^{-4}$              |

- (i) Use the results from Table 2.1 to plot another graph on the grid in Figure 2.3 to show the relationship between  $[\text{NH}_3]$  and time with the nickel-loaded silica catalyst. Use a cross (x) to plot each data point. Draw a line of best fit. Label the line 'silica'. [2]

- (ii) Identify the dependent variable in this experiment.

..... [1]

- (d) Use the line of best fit in Figure 2.3 for **tungsten** as a catalyst to answer **2(d)(i)**, **2(d)(ii)** and **2(d)(iii)**.

- (i) The line for tungsten is of the form  $y = mx + c$ . State the value of  $c$ .

..... [1]

- (ii) The student suggests the graph shows that the results for tungsten are reliable.

Explain how the graph supports this suggestion.

.....  
 ..... [1]

- (iii) The student concludes that the reaction using tungsten is zero order with respect to  $[\text{NH}_3]$ . State whether the results support the student's conclusion.

Explain your answer.

.....  
 ..... [1]

- (e) Use your line of best fit in Figure 2.3 for **silica** to calculate the half-life,  $t_{\frac{1}{2}}$ , in s, starting at time = 0 s.

State the coordinates of both points you use in your calculation.

coordinates 1 ..... coordinates 2 .....

half-life = ..... s  
[2]

- (f) In another experiment, a student finds that the half-life remains constant and that its value is 550 s. The student starts with  $[\text{NH}_3] = 4.00 \times 10^{-3} \text{ mol dm}^{-3}$ .

Predict the time taken, in s, for  $[\text{NH}_3]$  to fall to  $2.5 \times 10^{-4} \text{ mol dm}^{-3}$ .

time taken = ..... s [1]

[Total: 14]

### 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)<br>$V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ 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 <sup>-1</sup> K <sup>-1</sup> )                                                    |

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The Periodic Table of Elements

| Group |   |                           |  |  |  |  |  |  |  |  |  |  |  |    |    |    |    |    |    |
|-------|---|---------------------------|--|--|--|--|--|--|--|--|--|--|--|----|----|----|----|----|----|
| 1     | 2 | 1                         |  |  |  |  |  |  |  |  |  |  |  | 13 | 14 | 15 | 16 | 17 | 18 |
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