14–16 years

Titrating sodium hydroxide with hydrochloric acid

ROYAL SOCIETY OF CHEMISTRY

Education
Inspiring your teaching and learning

Learning objectives

1. Set up and carry out a neutralisation reaction by titration.
2. Calculate the concentration of hydrochloric acid using experimental results.
3. Produce a pure sample of sodium chloride crystals from sodium chloride solution.
4. Accurately record experimental observations and data.
5. Calculate the percentage yield of sodium chloride (challenge).

Today's challenge

Table salt is used in cooking. It is also added to our food to make it taste better.

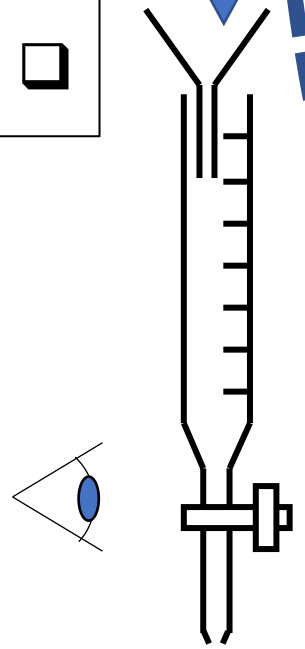
The chemical name for table salt is sodium chloride.

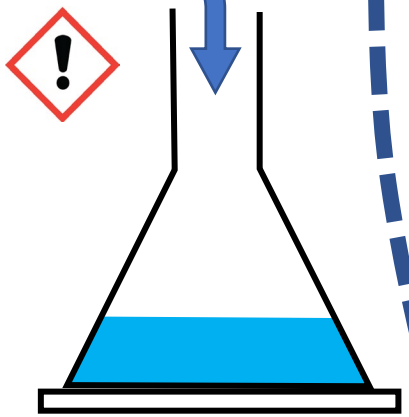
Sodium chloride solution can be made in a neutralisation reaction by reacting sodium hydroxide with dilute hydrochloric acid.

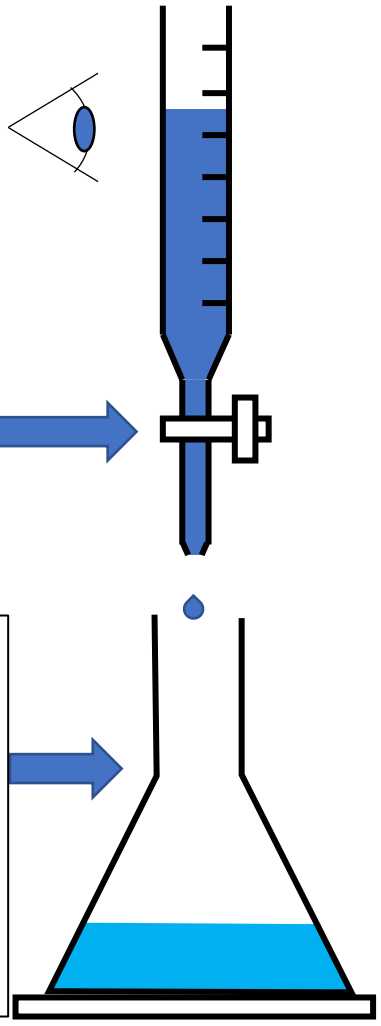
Your challenge is to produce a pure sample of sodium chloride crystals, starting with a sample of sodium hydroxide solution and dilute hydrochloric acid.

Stage 1

1. Fill to 0.0 cm^3 with HCl ❑
2. Tap is closed ❑
3. Pipette 25 cm^3 of NaOH ❑
4. Add 2 drops methyl orange ❑
5. Add HCl and .... ❑
6. ... swirl until colour changes from yellow–orange to red ❑
7. Measure and record volume ❑







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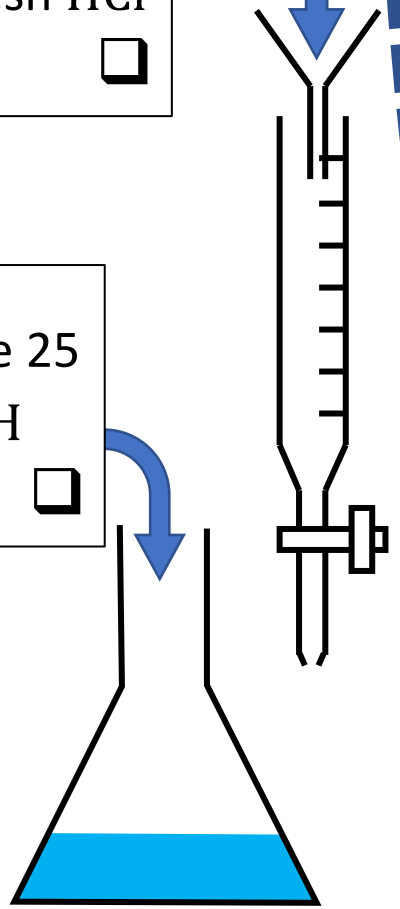
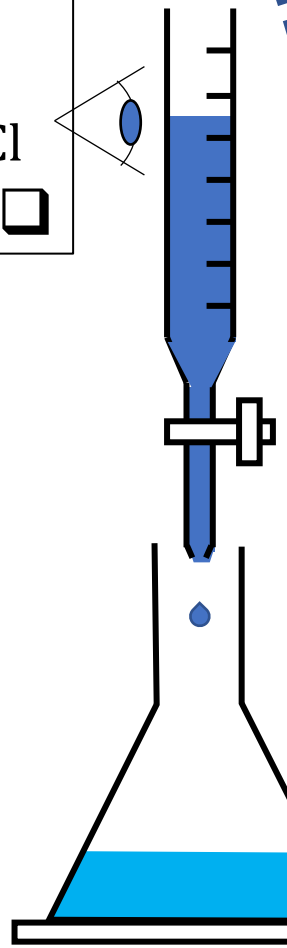
❶ Refill to 0.0 cm^3 with fresh HCl ❑

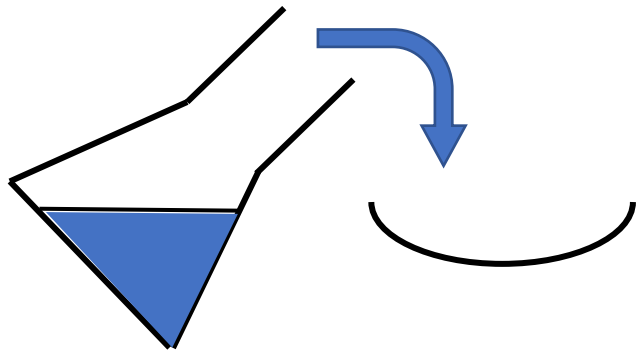
❷ Pipette 25 cm^3 of NaOH ❑



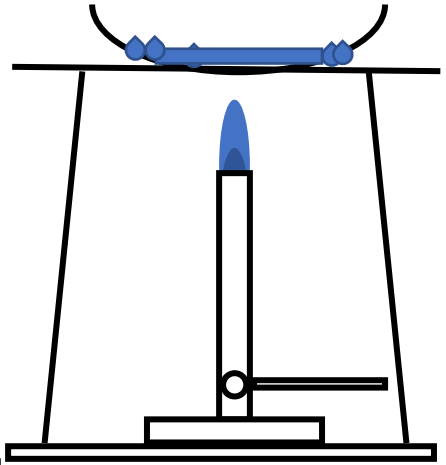
❸ Add measured volume of HCl ❑



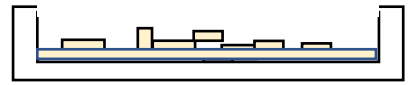
❶ Pour sodium chloride solution into an evaporating basin ❑



❷ Reduce volume by heating ❑



❸ Pour into a crystallising dish ❑



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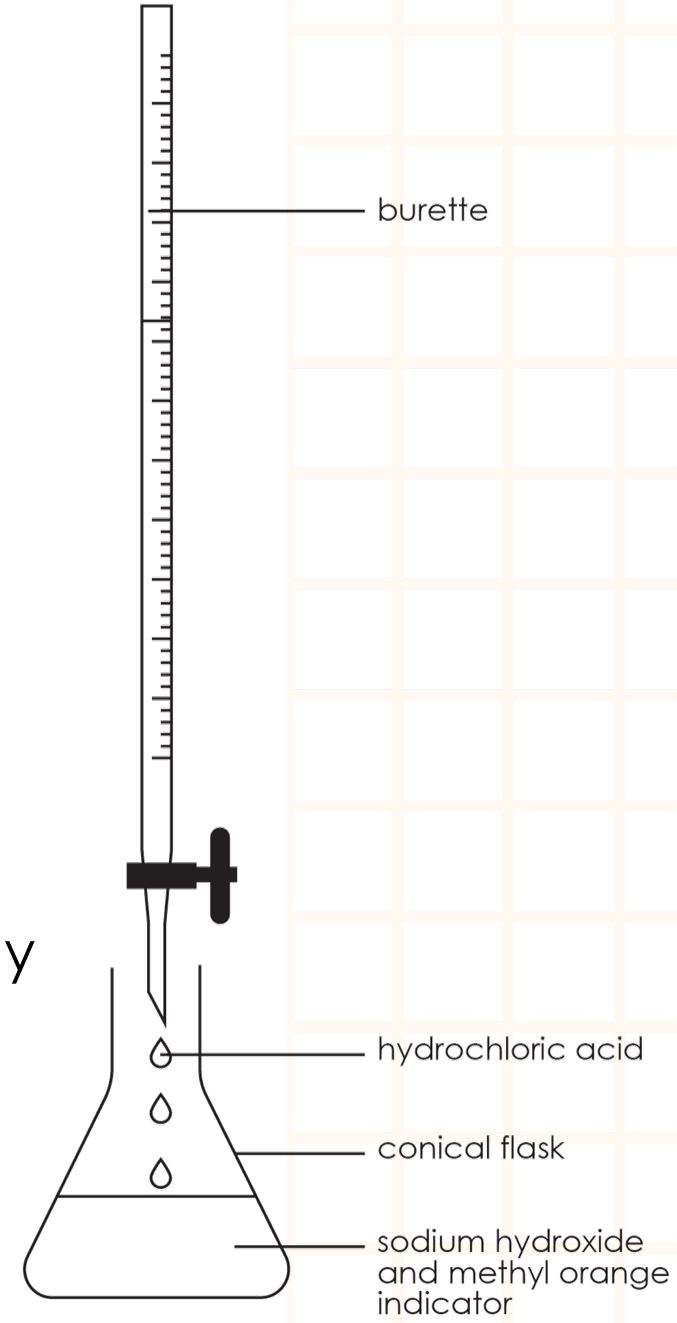
Stage 2

Stage 3

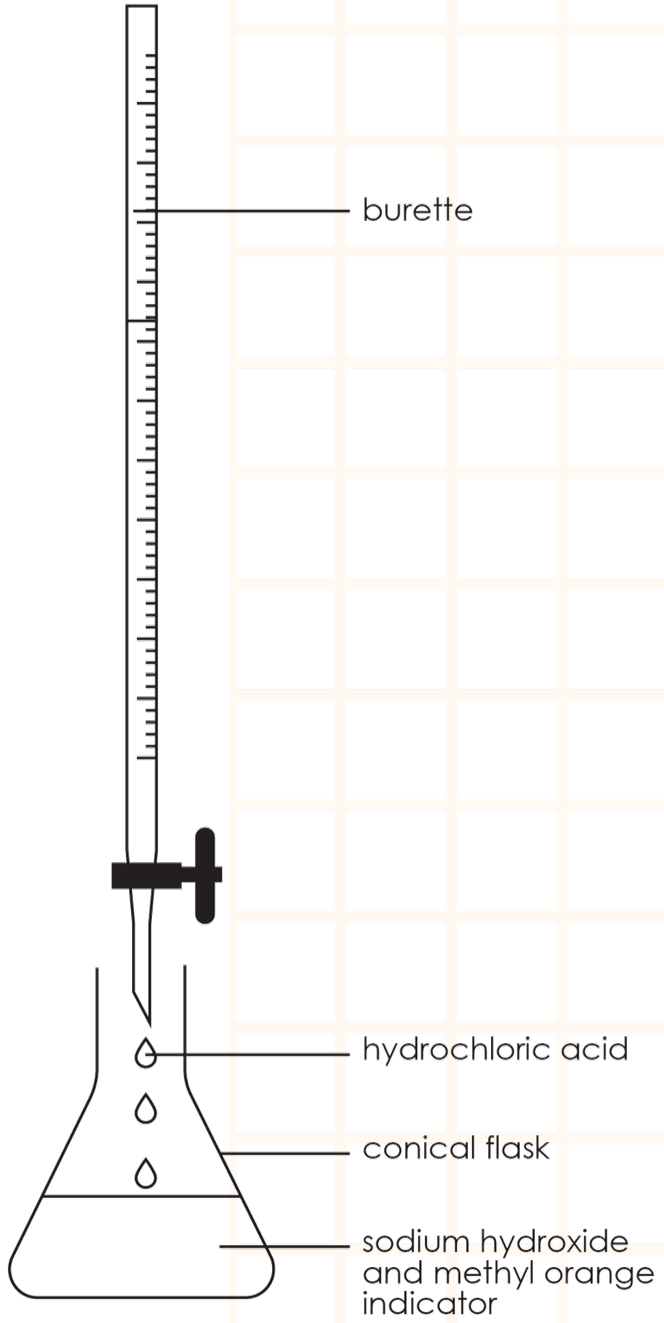
Stage 1: method

1. Using a small funnel, fill the burette with 0.4 M hydrochloric acid to the zero mark.
2. Use a pipette with pipette filler to transfer 25 cm^3 of 0.4 M sodium hydroxide solution to the conical flask.
3. Add two drops of methyl orange indicator. Swirl gently.
4. Place the flask on a white tile under the burette tap
5. Add the hydrochloric acid to the sodium hydroxide solution in small volumes, swirling gently after each addition. Continue until the solution just turns from yellow-orange to red.
6. Record the reading on the burette.
7. Wash the solution down the sink.



Stage 1: questions

1. Name the products formed in this reaction.
2. Write a word equation for this reaction.
3. Write a symbol equation for the reaction.
4. Explain why methyl orange was added to the conical flask.
5. Record the volume of hydrochloric acid needed to neutralise the sodium hydroxide.
6. Calculate the concentration of the hydrochloric acid.



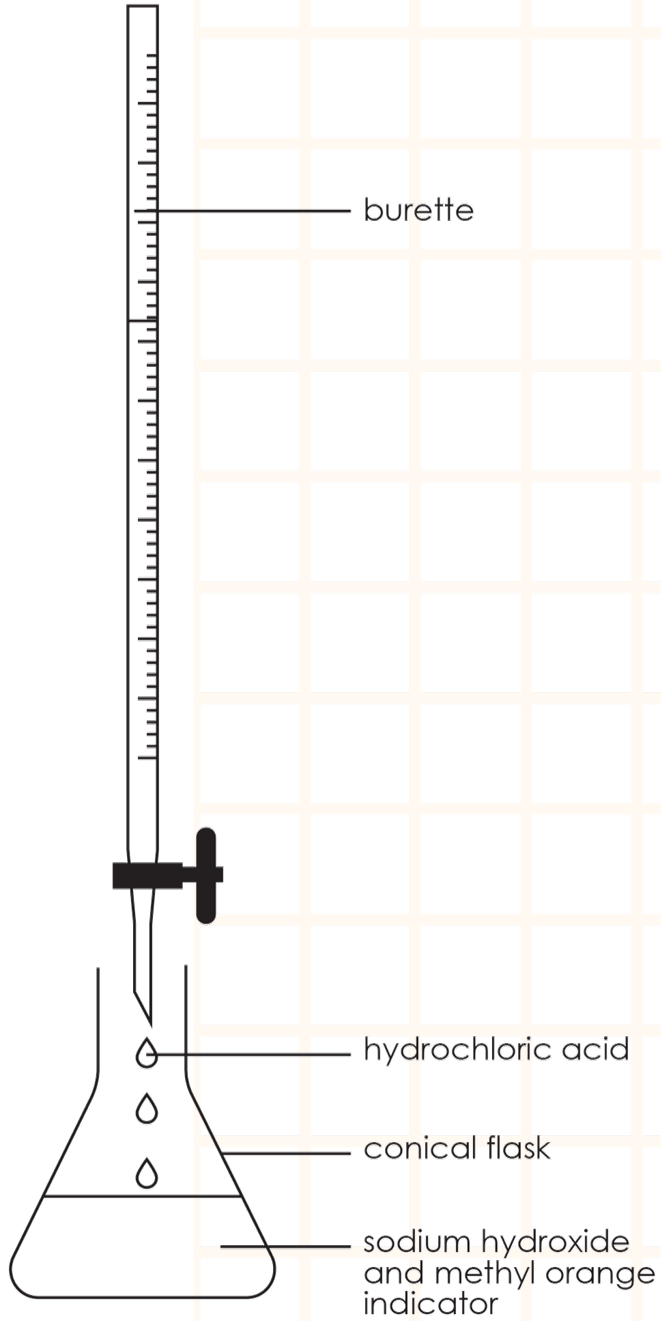
Stage 1: questions (scaffolded)

1. Name the products formed in this reaction.
2. Write a word equation for this reaction.
3. Match the compounds to the correct formula

H_2O	sodium hydroxide
HCl	sodium chloride
$NaCl$	water
$NaOH$	hydrochloric acid

Now use the formulas to write a balanced symbol equation for the reaction.

4. Explain why methyl orange was added to the conical flask.
5. State the volume of hydrochloric acid needed to neutralise the sodium hydroxide.
6. Using the formula on the worksheet and your answers to questions 3 and 5, follow the steps on the worksheet to calculate the concentration of hydrochloric acid used in the titration.



Example calculation

During a titration, 22.3 cm^3 of HCl was neutralised by 20.0 cm^3 of 0.5 mol/dm^3 $NaOH$. Calculate the concentration of the HCl.

$$\text{concentration } (mol/dm^3) = \frac{\text{number of moles}}{\text{volume } (dm^3)}$$

Step 1 Calculate the number of moles of $NaOH$.

To rearrange the formula, multiply each side by volume

To convert cm^3 to dm^3 divide by 1000

Step 2 Use the symbol equation to work out the mole ratio.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Use the big numbers in the equation to work out the mole ratio. In this case there is a 1 in front of each formula

The mole ratio of $HCl : NaOH$ is 1:1

Step 3 Use the mole ratio to calculate the number of moles of HCl.

Moles of HCl = moles of $NaOH$ = 0.01 moles

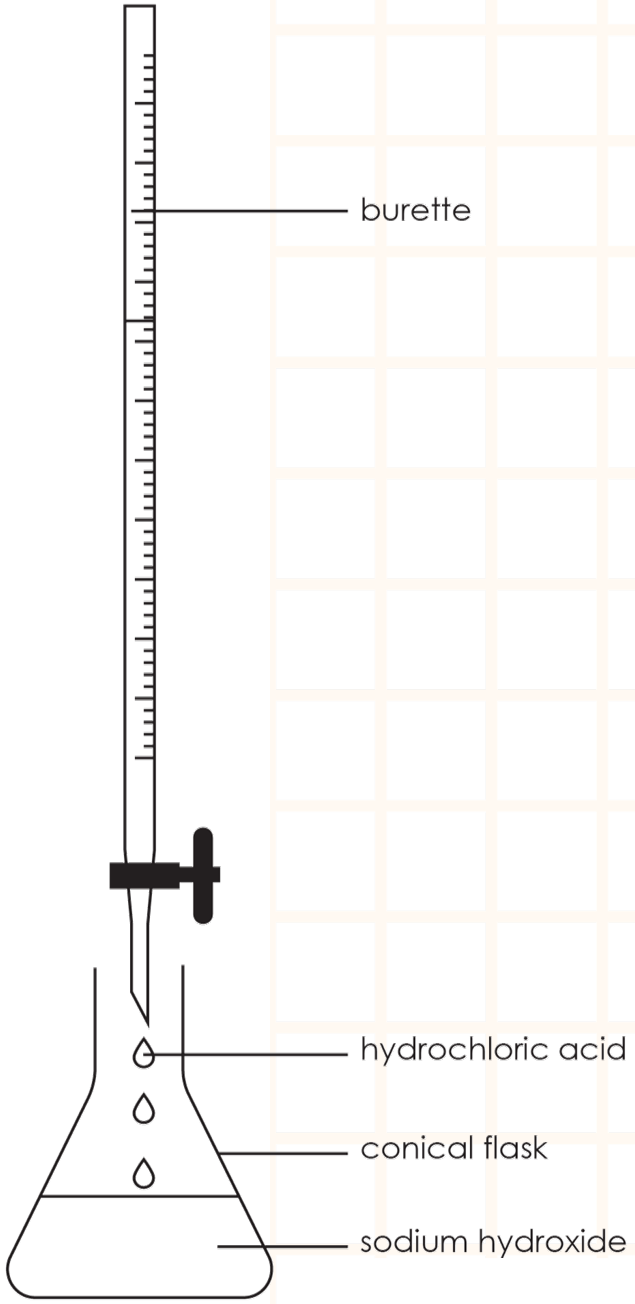
Step 4 Substitute the concentration formula to calculate the concentration of HCl.

$$\text{concentration} = 0.01/0.0223 = \mathbf{0.43\ mol/dm^3}$$

Stage 2: method

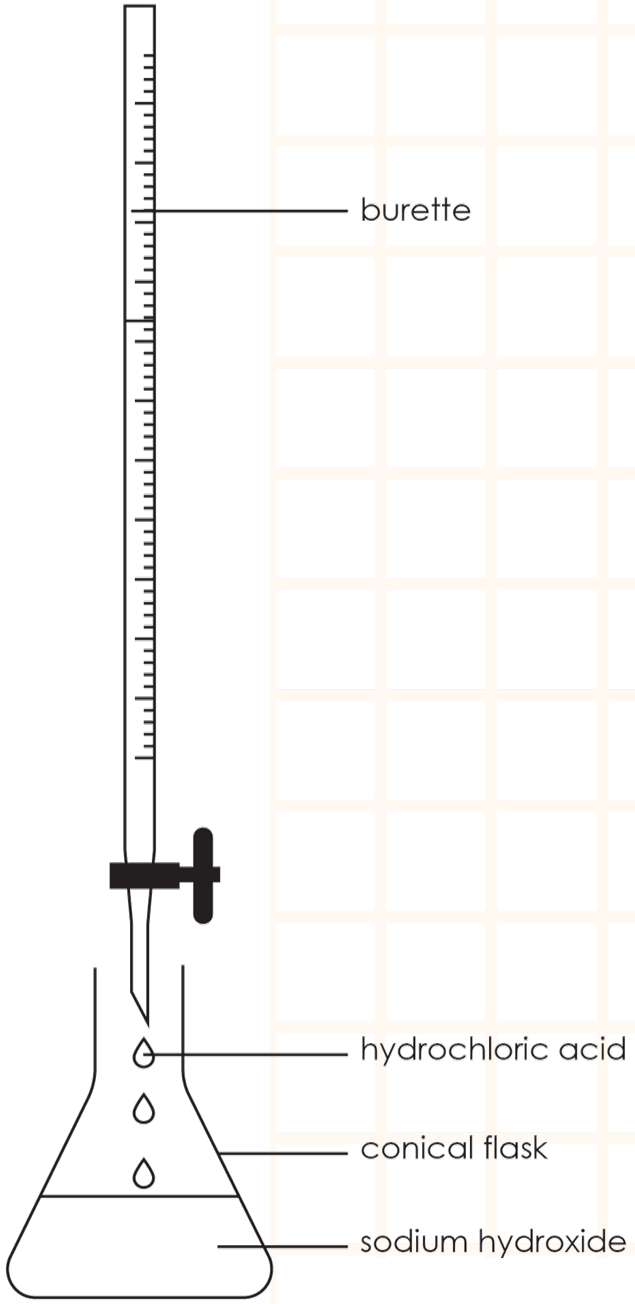
1. Refill the burette to the zero mark with fresh 0.4 M hydrochloric acid.
2. Use a pipette to transfer 25 cm^3 of 0.4 M sodium hydroxide solution to the conical flask.
3. Carefully add the same volume of hydrochloric acid as you used in stage 1, to the sodium hydroxide in the conical flask.
4. **Do not add any indicator.**

You now have a pure sample of sodium chloride solution in your conical flask.



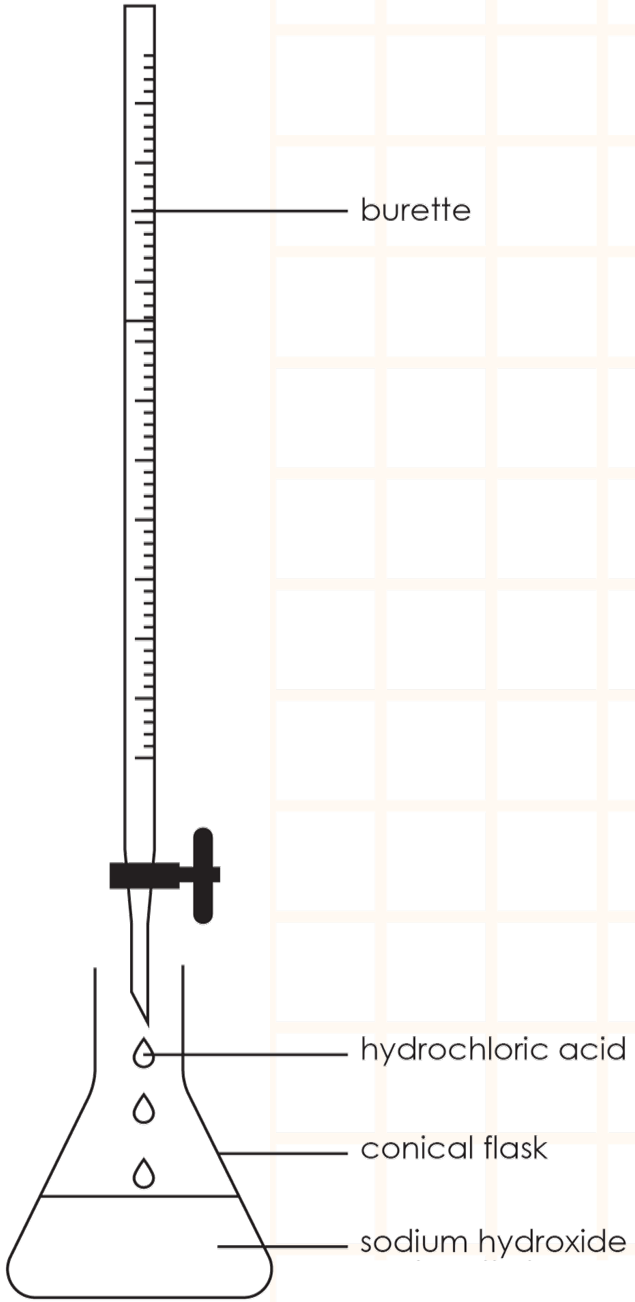
Stage 2: questions

1. Explain why must you use another 25 cm^3 of sodium hydroxide solution, rather than making your crystals from the solution in stage 1.
2. Explain why an indicator was not used in stage 2 of the process.
3. Explain why it is good practice to repeat stage 1 and work out the average reading.
4. Describe how could you test to see if all the hydrochloric acid had been neutralised without contaminating the product.



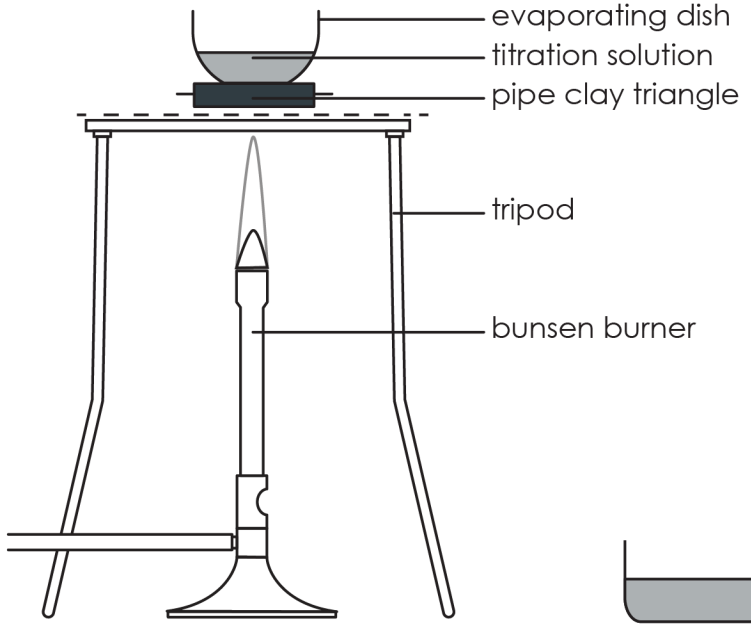
Stage 2: questions (scaffolded)

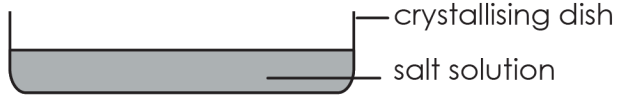
1. State the chemicals present after the titration in stage 1.
2. State the products that would remain if you evaporated the water from the solution produced in stage 1.
3. Using your answers to question 1 and 2, explain why you don't use indicator to produce pure crystals of sodium chloride in stage 2.
4. Explain why the same volume of sodium hydroxide is needed for stage 2.
5. Explain how you could test to see whether the solution is neutral without using an indicator.



Stage 3: method

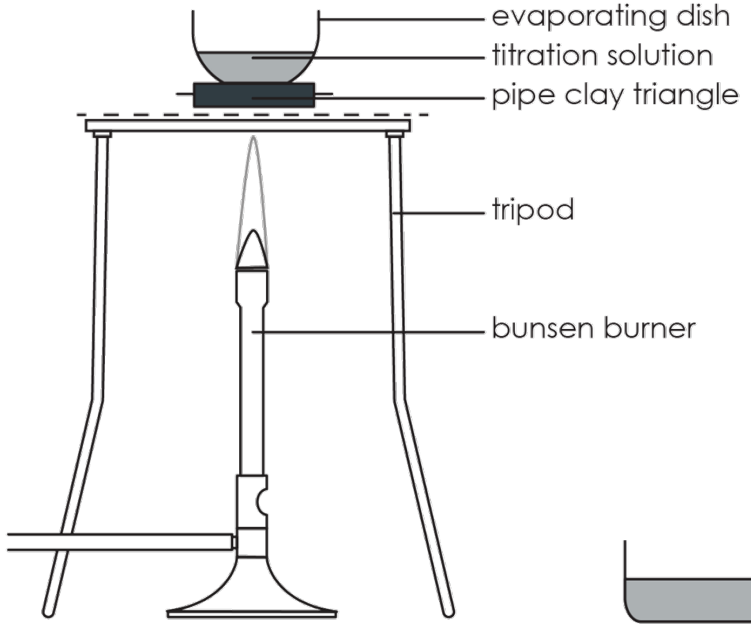
1. Pour the solution into an evaporating basin.
2. Reduce the volume of the solution to about half by heating over a low to medium Bunsen burner flame.
3. Allow to cool and then pour into a crystallising dish.
4. Leave the concentrated solution to evaporate further in the crystallising dish.
5. Record the mass of the dry crystals.
6. Examine the crystals under the microscope.

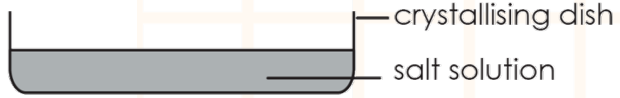




Stage 3: questions

1. Explain what was happening when the titration solution was being heated in the evaporation basin.
2. Record the mass of the crystals.
3. Sketch what you see when you look at the salt crystals under the microscope.
4. Describe the shape of the crystals.
5. Use your knowledge of ionic bonding to explain the shape of the crystals. Include a lattice diagram in your answer.





Challenge question

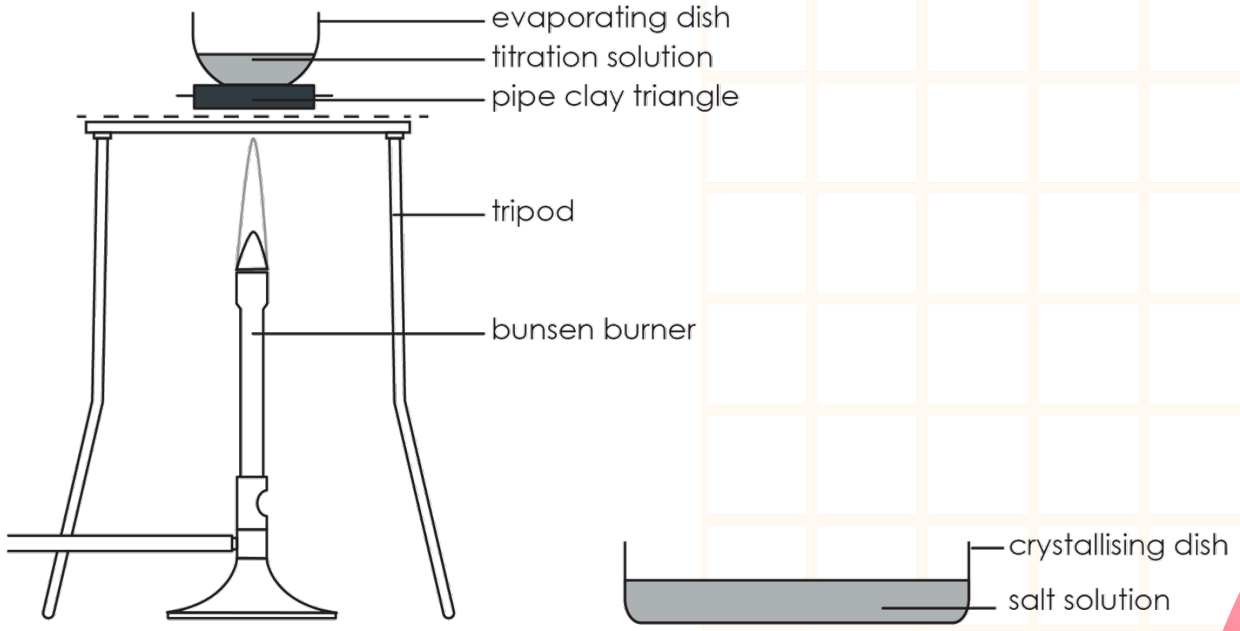
Calculate the percentage yield of sodium chloride. Show all your working.

Stage 3: questions (scaffolded)

1. Complete the sentences by crossing out the incorrect words.

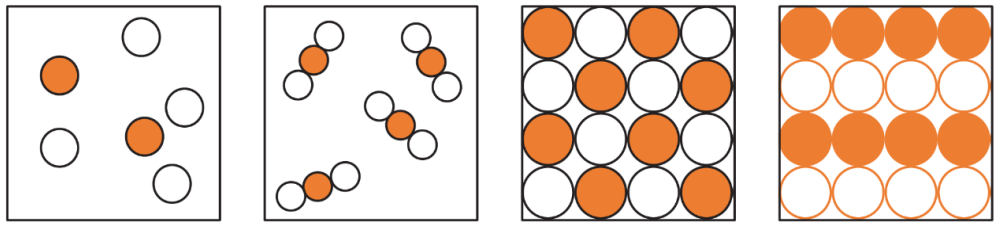
As the water molecules **evaporate/condense**, a **less/more** concentrated solution of sodium chloride **molecules/ions** forms in the basin. Eventually the solution becomes **dry/saturated** and sodium chloride crystals start to form.

2. Record the mass of the crystals.
3. Sketch what you see when you look at the salt crystals under the microscope.
4. Describe the shape of the crystals.
5. Use your knowledge of ionic bonding to explain the shape of the crystals. Include a lattice diagram in your answer.

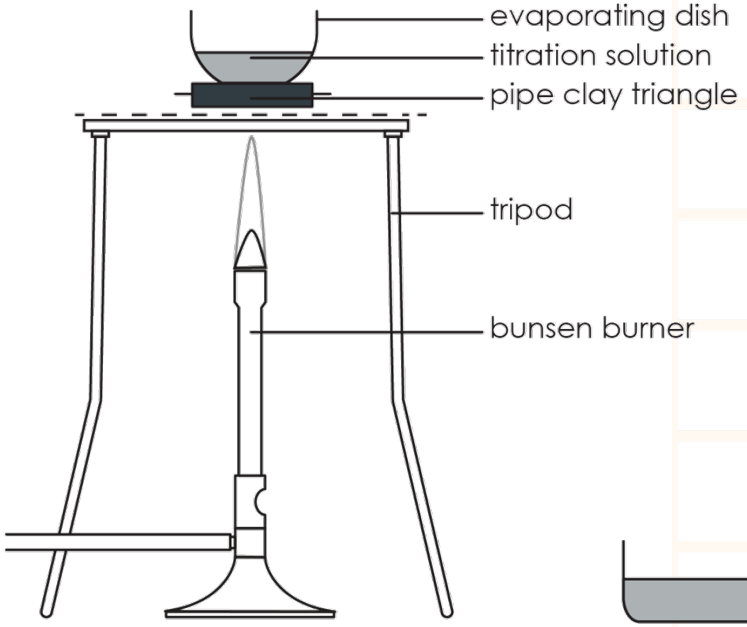


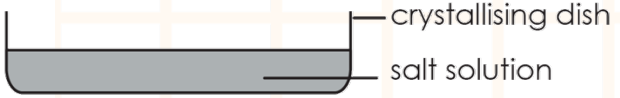
Questions: stage 3

6. Select the diagram that best represents the structure of sodium chloride crystals.



Give a reason for your answer.





Support questions: stage 3

Challenge question: hints and tips

$$\%\ \text{yield} = \frac{\text{actual mass}}{\text{theoretical mass}} \times 100$$

To determine the actual mass, you will need to weigh your crystals.

To calculate the theoretical mass, you will need to use the following:

- A_r Na = 23, A_r Cl = 35.5
- the balanced equation for the reaction
- the starting concentrations and volumes used in stage 1 of the practical

You will need to use the following formula:

$$\text{concentration (mol/dm}^3\text{)} = \frac{\text{moles (mol)}}{\text{volume (dm}^3\text{)}}$$

$$\text{moles} = \frac{\text{mass}}{M_r} \quad M_r = \text{sum of } A_r$$

Remember to show all your working.

You may wish to tabulate your data.

Learning objectives - review

1. Set up and carry out a neutralisation reaction by titration.
2. Calculate the concentration of hydrochloric acid using experimental results.
3. Produce a pure sample of sodium chloride crystals from sodium chloride solution.
4. Accurately record experimental observations and data.
5. Calculate the percentage yield of sodium chloride (challenge).

How did you do?