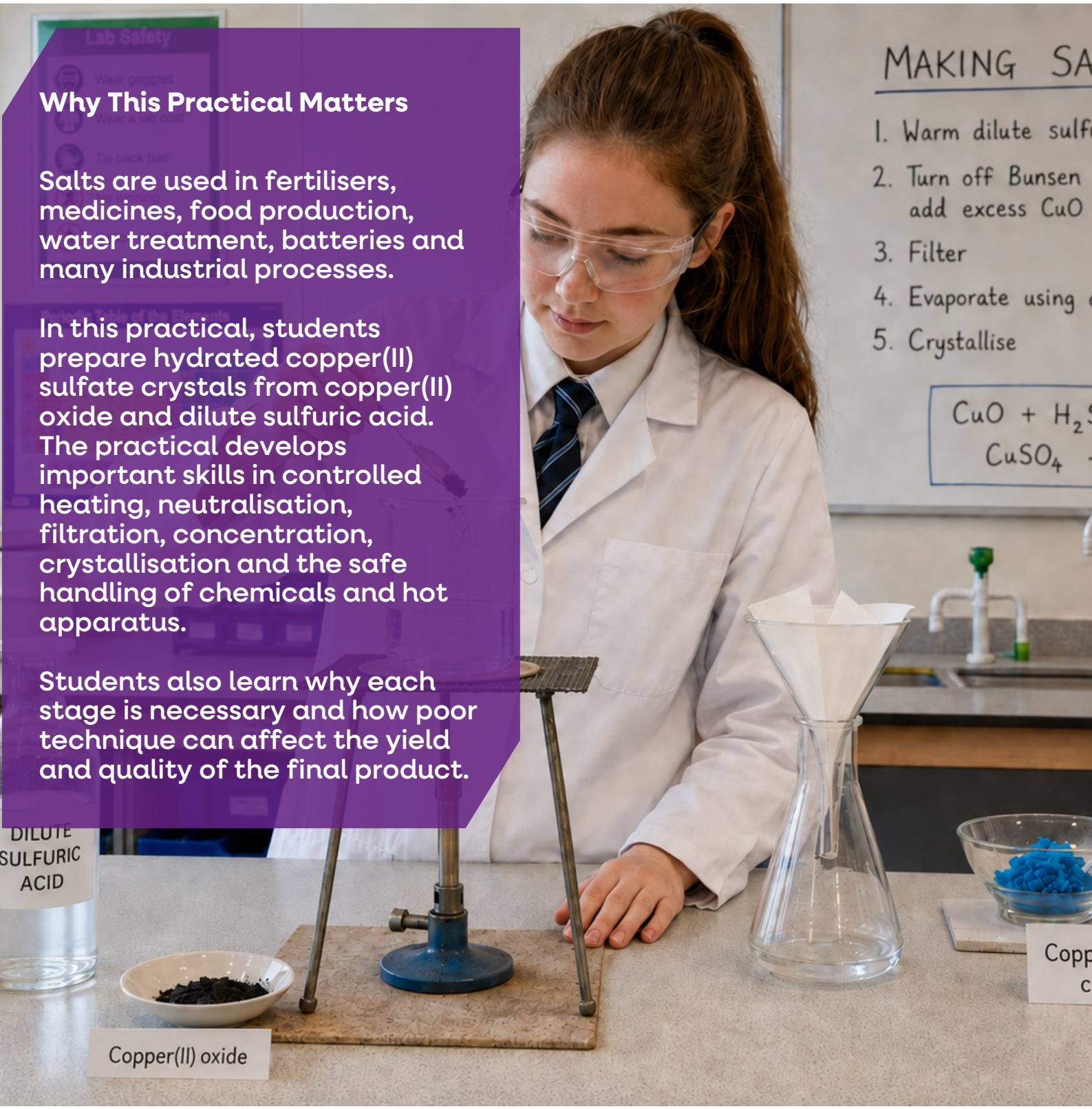
GCSE Chemistry Practical Guide

Chemical Changes

Making Salts

An enhanced GCSE practical guide covering safe salt preparation, neutralisation, filtration, controlled concentration, crystallisation, percentage yield, troubleshooting, retrieval practice and examination support.



Why This Practical Matters

Salts are used in fertilisers, medicines, food production, water treatment, batteries and many industrial processes.

In this practical, students prepare hydrated copper(II) sulfate crystals from copper(II) oxide and dilute sulfuric acid. The practical develops important skills in controlled heating, neutralisation, filtration, concentration, crystallisation and the safe handling of chemicals and hot apparatus.

Students also learn why each stage is necessary and how poor technique can affect the yield and quality of the final product.

This resource is provided as a practical support guide to accompany laboratory equipment. Teachers should adapt procedures and risk assessments to suit their curriculum requirements, examination board specifications and local laboratory policies.

Practical Overview

In this practical, students prepare hydrated copper(II) sulfate crystals by reacting dilute sulfuric acid with copper(II) oxide, an insoluble base.

The acid is warmed and then removed from the heat before copper (II) oxide is added in small portions. Copper(II) oxide is added until a persistent excess remains, showing that all the acid has reacted. The excess solid is removed by filtration. The clear blue filtrate is then concentrated using a water bath or electric heater and left to cool so that hydrated copper(II) sulfate crystals form.

The practical develops skills in controlled heating, recognising excess reactant, filtration, evaporation, crystallisation, recording observations and evaluating yield and product quality.

Learning Objectives

By completing this practical, students should be able to:

- prepare a soluble salt from an acid and an insoluble base;
- explain why copper(II) oxide is added in excess;
- recognise the reaction as neutralisation;
- distinguish between the residue and the filtrate;
- explain how the solution is evaporated to prevent the crystals from drying out'
- collect and surface-dry hydrated crystals;
- write the balanced equation with state symbols;
- describe the reaction using ions, including both those involved in the neutralisation and the spectator ions;
- calculate actual and percentage yield when appropriate;
- identify sources of product loss or contamination.

Scientific Background

A salt is an ionic compound formed when the hydrogen ions in an acid are replaced by metal ions or ammonium ions.

Hydrogen ions from sulfuric acid react at the surface of the copper(II) oxide. The oxide part of the solid forms water, while copper(II) ions enter the solution. Sulfate ions remain in the solution throughout the neutralisation.

Copper(II) oxide is added until some black solid remains after thorough stirring. This persistent excess shows that the sulfuric acid has reacted completely. The excess copper(II) oxide is then removed as the residue during filtration. The blue filtrate contains dissolved copper(II) ions and sulfate ions.

Controlled evaporation removes some of the solvent and concentrates the solution. As the concentrated solution cools, blue hydrated copper(II) sulfate crystals form. These are commonly represented as $CuSO_4 \cdot 5H_2O$.

Surface drying removes adhering mother liquor and surface water. It must not be described as removing the water of crystallisation from inside the blue crystals.

Overall reaction

$$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$$

Net ionic equation

$$CuO(s) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l)$$

Equipment Required

Per pair or working group

Reaction and filtration

- 100 cm^3 beaker
- 50 cm^3 or 100 cm^3 measuring cylinder
- glass stirring rod
- spatula
- filter funnel
- filter paper
- conical flask
- retort stand, boss and clamp for supporting the funnel

Heating and crystallisation

- Bunsen burner
- tripod
- gauze
- heatproof mat
- 250 cm^3 beaker for the water bath
- evaporating basin
- crystallising dish or labelled watch glass
- suitable tongs for hot apparatus
- cool white tile or spotting tile for testing the concentration endpoint

Equipment Required

Per pair or working group

Other

- wash bottle containing distilled water
- additional filter paper for surface drying
- labelled copper-containing waste container
- balance, only when crystal mass or percentage yield is being measured

Personal protective equipment

- splash-resistant eye protection
- laboratory coat
- closed footwear
- long hair tied back and ties secured away from the apparatus

Chemicals

- 40 cm^3 of 1.0 mol dm^{-3} sulfuric acid per group for the AQA-aligned method
- approximately 4 g of copper(II) oxide available per group, added to persistent excess rather than as a single measured addition

MAKING SALTS APPARATUS SETUP

Equipment needed to prepare relatively pure, surface-dry hydrated salt crystals from an acid and an insoluble base.

OVERVIEW

This setup shows the equipment used to prepare hydrated copper(II) sulfate crystals. The acid is warmed first. The Bunsen burner is then turned off before copper(II) oxide is added. Excess solid is removed by filtration and the filtrate is concentrated using a water bath before crystallisation.

SAFETY REMINDERS

Wear eye protection at all times.

Turn off the Bunsen burner before adding copper(II) oxide.

Use a heatproof mat. Handle a hot basin only with suitable tongs and place it in a designated cooling area.

Add copper(II) oxide in small portions to reduce frothing and splashing.

EQUIPMENT

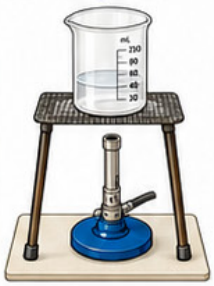
1. 100 cm^3 beaker containing 40 cm^3 of 1.0 mol dm^{-3} sulfuric acid
2. Glass stirring rod
3. Spatula / scoopula
4. Copper(II) oxide
5. Three-legged tripod
6. Gauze
7. Bunsen burner
8. Heatproof mat
9. Filter funnel
10. Filter paper
11. Conical flask (filtration receiver)
12. Evaporating basin
13. Distilled water wash bottle
14. Safety goggles
15. 250 cm^3 beaker used as a water bath
16. Crystallising dish or watch glass
17. Tongs for hot apparatus
18. Clamp stand to support the funnel

BEFORE YOU START – CHECK!

- Glassware is clean. The receiving flask, evaporating basin and crystallising dish are dry where required.
- Bunsen burner works and gas tap is off.
- Gauze is centred on the tripod.
- Filter paper fits the funnel properly.
- The acid concentration and volume have been checked.
- The water bath and hot-apparatus cooling area are ready.
- A labelled copper-containing waste container is available.

EXAMPLE ARRANGEMENTS

A. Warming the acid



B. Concentrating the filtrate

Evaporating basin heated in a water bath (no direct flame).

KEY REMINDERS

- Add the insoluble base in small portions with stirring.
- Make sure some solid remains to show excess.
- Filter carefully to collect a clear solution.
- Concentrate the filtrate using a water bath or electric heater. Stop when a cooled test drop crystallises or when the first crystals appear at the edge.
- Allow to cool undisturbed for crystal formation.

CHEMISTRY PRACTICAL

Safety Note: This practical involves acids and a Bunsen burner. Follow your teacher's instructions at all times.

Good technique = reliable results

Method

- Measure 40 cm^3 of 1.0 mol dm^{-3} sulfuric acid and transfer to the beaker.
- Slowly warm the beaker of acid.
- Turn off the Bunsen burner and carefully place the beaker on to the heatproof mat.
- Add CuO in small portions with stirring until persistent excess remains.
- Allow the mixture to cool.
- Filter into a conical flask.
- Transfer the filtrate to an evaporating basin.
- Concentrate it using a water bath or approved electric heater.
- Test a cooled drop or stop heating at the first appearance of edge crystals.
- Cool, collect, optionally wash and surface-dry the hydrated crystals ready for weighing.

Chemical Equation

Word equation

Copper(II) oxide + sulfuric acid → copper(II) sulfate + water

Balanced equation with state symbols

$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

Net ionic equation

$CuO(s) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l)$

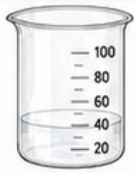
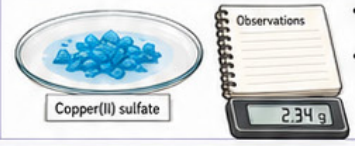
What is Happening?

- Copper(II) oxide is an insoluble basic oxide.
- Hydrogen ions from the sulfuric acid react at the surface of the copper(II) oxide.
- Water is formed and copper(II) ions enter the solution.
- Sulfate ions remain in the solution and act as spectator ions during the neutralisation.
- The blue solution contains dispersed copper(II) ions and sulfate ions, not separate copper sulfate molecules.
- Controlled evaporation removes some of the solvent and produces a more concentrated solution.
- As the solution cools, hydrated copper(II) sulfate crystals form.
- Surface drying removes adhering solution; it does not remove the water of crystallisation from the blue crystals.

Blue hydrated crystals: $CuSO_4 \cdot 5H_2O$

MAKING SALTS
STEP-BY-STEP EXPERIMENTAL WORKFLOW

Investigating the reaction of an acid with an insoluble base to produce hydrated copper(II) sulfate crystals.

STEP		WHAT TO DO & WHY
1 MEASURE THE ACID Measure 40 cm^3 of 1.0 mol dm^{-3} sulfuric acid into a 100 cm^3 beaker.		• Measure 40 cm^3 of 1.0 mol dm^{-3} sulfuric acid into a 100 cm^3 beaker. **Why?** A measured amount is needed so the method can be repeated and quantitative work can be linked to the preparation.
2 WARM THE ACID Heat gently until the acid is hot and close to boiling. Do not allow it to boil.		• Warm the acid gently until it is hot and close to boiling. Do not allow it to boil. **Why?** Heating increases the rate of reaction, but the solution should remain controlled and not boil vigorously.
3 TURN OFF THE BUNSEN BURNER Close the gas tap before adding copper(II) oxide.		• Turn off the Bunsen burner and close the gas tap before adding copper(II) oxide. **Why?** This reduces the risk of frothing, splashing and unnecessary heating while the solid is added.
4 ADD COPPER(II) OXIDE GRADUALLY Add small spatula portions and stir after each addition. Continue until some black solid remains after thorough stirring.		• Add copper(II) oxide in small spatula portions. • Stir after each addition and continue until some black solid remains after thorough stirring. **Why?** Copper(II) oxide is added in excess so that all of the sulfuric acid reacts. The excess solid can be removed later by filtration.
5 ALLOW TO COOL AND FILTER Allow the mixture to cool. Filter it into a conical flask. The black excess solid is the residue and the clear blue solution is the filtrate.		• Allow the mixture to cool before filtration. • Filter it into a conical flask. The black excess solid is the residue and the clear blue solution is the filtrate. **Why?** Filtration removes the excess insoluble copper(II) oxide and leaves the copper(II) sulfate solution.
6 CONCENTRATE THE FILTRATE Transfer the blue filtrate to an evaporating basin and heat it using a water bath or approved electric heater. Do not boil it to dryness.		• Transfer the blue filtrate to an evaporating basin. • Heat it using a water bath or approved electric heater. • Do not boil it to dryness. **Why?** Concentrating the filtrate removes some solvent so crystals can form when the solution cools.
7 ALLOW CRYSTALS TO FORM Transfer the concentrated solution to a labelled crystallising dish and leave it to cool slowly and undisturbed.		• Transfer the concentrated solution to a labelled crystallising dish and leave it to cool slowly and undisturbed. **Why?** As the concentrated solution cools, hydrated copper(II) sulfate crystals form from the mother liquor.
8 COLLECT AND, IF DIRECTED, WASH THE CRYSTALS Separate the crystals from the mother liquor. Rinse rapidly with a very small amount of cold distilled water.		• Separate the crystals from the mother liquor. • Rinse rapidly with a very small amount of cold distilled water. **Why?** Washing removes adhering mother liquor and soluble surface impurities.
9 SURFACE-DRY AND RECORD Gently blot between filter papers or air-dry on a labelled watch glass. Record the crystal appearance and mass if required.		• Gently blot the crystals between filter papers or air-dry them on a labelled watch glass. • Record the crystal appearance and mass if required. **Why?** Surface-dry crystals can be weighed, but their colour and appearance alone do not prove purity.

KEY POINTS

1. Use an insoluble base so any excess can be removed by filtration.
2. Add copper(II) oxide gradually with stirring.
3. Heat only during the specified warming and concentration stages. The burner must be off during copper(II) oxide addition and filtration.
4. Allow the concentrated solution to cool slowly and undisturbed for crystal formation.
5. Handle a hot basin with suitable tongs.
6. Use only a very small amount of cold distilled water if the crystals are washed.

SAFETY REMINDERS

- Wear eye protection at all times.
- Handle acids and hot equipment with care.
- Use a heatproof mat and suitable tongs for hot apparatus.
- Allow hot equipment to cool before handling.

CHEMISTRY PRACTICAL

GOOD TECHNIQUE = RELIABLE RESULTS
Work carefully, follow each step and keep your bench space tidy.

Good technique = reliable results

Results Table

Measurement or observation	Student result
Sulfuric acid concentration / mol dm^{-3}	
Sulfuric acid volume / cm^3	
Initial appearance of sulfuric acid	
Appearance while copper(II) oxide is added	
Evidence that copper(II) oxide is in excess	
Appearance of residue	
Appearance of filtrate	
Evidence that the filtrate is sufficiently concentrated	
Appearance of crystals after cooling	
Mass of surface-dry crystals / g, if measured	

Expected Observations

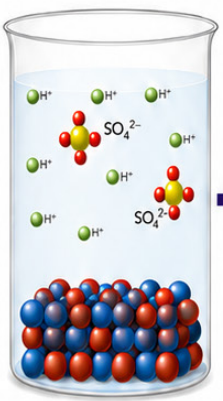
Stage	Expected observation	Interpretation
Initial sulfuric acid	Colourless solution	No copper(II) ions are present initially
First additions of CuO	Black solid gradually disappears; solution becomes blue	Copper(II) oxide is reacting and copper(II) ions are entering solution
Final CuO addition	Some black solid remains after thorough stirring	Copper(II) oxide is in excess and the acid has reacted completely
Filtration	Black residue on the paper; clear blue filtrate collected	Excess CuO has been removed
Concentration	Volume decreases and blue colour becomes more intense	Some solvent has evaporated
Cooling	Blue crystals begin to form on the outer edges	Hydrated copper(II) sulfate is crystallising
Collection and drying	Blue surface-dry crystals obtained	Volume of water has been reduced

HOW MAKING SALTS WORKS
(PARTICLE-LEVEL)

Acid + insoluble base → dissolved salt solution → controlled concentration → hydrated crystals

1 BEFORE THE REACTION

Dilute sulfuric acid contains hydrogen ions and sulfate ions. Copper(II) oxide is an insoluble ionic solid.

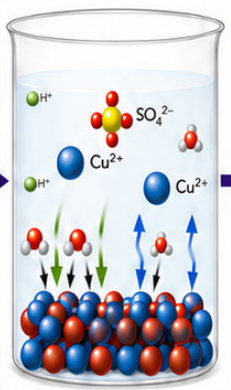


- $CuO(s)$ (solid lattice)
- $H^+(aq)$ Hydrogen ion
- $SO_4^{2-}(aq)$ Sulfate ion

2 DURING THE REACTION

At the surface of the solid, hydrogen ions react with the oxide part of copper(II) oxide. Water forms and $Cu^{2+}(aq)$ ions enter the solution.

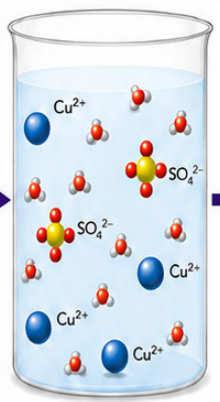
$$CuO(s) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l)$$



- $Cu^{2+}(aq)$ Copper(II) ion
- $H^+(aq)$ Hydrogen ion
- $H_2O(l)$ Water molecule

3 SALT SOLUTION

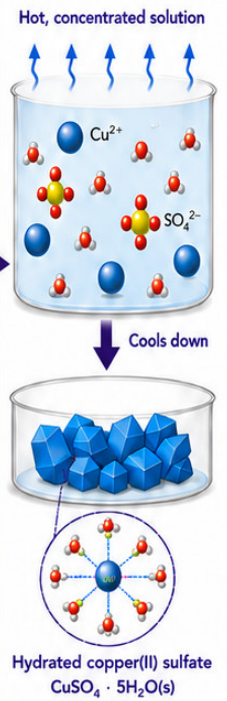
The clear blue filtrate contains dissolved $Cu^{2+}(aq)$ and $SO_4^{2-}(aq)$ ions. Sulfate ions are spectator ions during the neutralisation.



- $Cu^{2+}(aq)$ Copper(II) ion
- $SO_4^{2-}(aq)$ Sulfate ion
- $H_2O(l)$ Water molecule

4 CONCENTRATION AND CRYSTALLISATION

Controlled evaporation concentrates the solution. As the solution cools, copper(II) ions, sulfate ions and water become arranged in hydrated crystals.



Hydrated copper(II) sulfate
$CuSO_4 \cdot 5H_2O(s)$

KEY

- $Cu^{2+}(aq)$ Copper(II) ion
- $H^+(aq)$ Hydrogen ion
- $SO_4^{2-}(aq)$ Sulfate ion
- $H_2O(l)$ Water molecule
- $CuO(s)$ Copper(II) oxide (solid lattice)

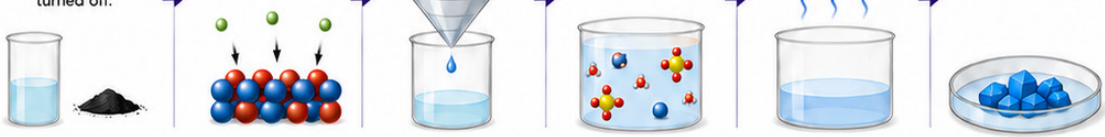
STATE SYMBOLS

(s)	solid
(aq)	aqueous
(l)	liquid
(g)	gas (water vapour)

Models are simplified and not drawn to scale.

SUMMARY: THE PROCESS IN SIX STEPS

1. Warm acid and copper(II) oxide are mixed after the burner is turned off.
2. Hydrogen ions react with copper(II) oxide.
3. Excess CuO is filtered off.
4. The filtrate contains dissolved Cu^{2+} and SO_4^{2-} ions.
5. Some solvent is evaporated.
6. Hydrated crystals form on cooling.



KEY IDEA

Hydrogen ions in the acid react with the oxide ions in solid copper(II) oxide to form water. Copper(II) ions enter the solution, while sulfate ions stay in solution as spectators. Concentrating the solution by controlled evaporation and then cooling allows hydrated copper(II) sulfate crystals to form.

FILTRATION, EVAPORATION & CRYSTALLISATION EXPLAINED

Three key processes used to separate excess reactant, concentrate the salt solution and form hydrated crystals.

1 FILTRATION

Remove the excess insoluble base

The cooled reaction mixture is poured through the filter paper.

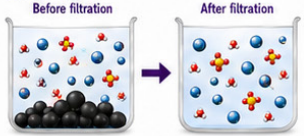
RESIDUE (on the filter paper): Excess insoluble base (e.g. copper(II) oxide).

FILTRATE (collected in flask): Clear blue copper(II) sulfate solution.

KEY POINTS

- Use a funnel and correctly fitted filter paper for clear separation.
- The excess solid is left behind as the residue.
- The filtrate is the clear salt solution ready for concentration.
- Where directed, rinse the reaction beaker and residue with a small quantity of distilled water to transfer trapped salt solution. Avoid excessive rinsing because this adds more solvent.

PARTICLE VIEW



TOP TIP: Rinse only where directed and use only a small quantity of distilled water.

2 EVAPORATION

Concentrate the salt solution

Some water molecules gain enough energy to leave the solution as water vapour.

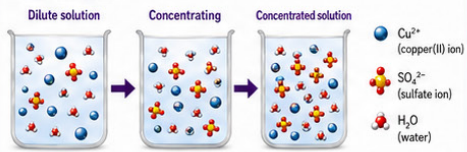
The dissolved copper(II) and sulfate ions remain in the solution as it becomes more concentrated.

Stop heating when a cooled test drop crystallises or when the first crystals appear at the edge. Do not evaporate the solution to dryness.

KEY POINTS

- Heat gently to avoid spitting and loss of solution.
- Water evaporates, so the solution becomes more concentrated.
- The dissolved ions remain in the solution during concentration.
- Do NOT heat to dryness.

PARTICLE VIEW



TOP TIP: Keep the solution below boiling and use the approved water-bath or electric-heater arrangement.

3 CRYSTALISATION

Form hydrated crystals

As the concentrated solution cools, its ability to keep the salt dissolved decreases. Hydrated copper(II) sulfate crystals form in the remaining mother liquor.

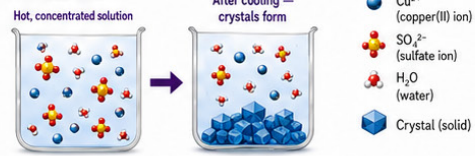
Larger, better-formed crystals are usually obtained when the solution cools slowly and remains undisturbed.

Crystals should be surface-dried on filter paper or in air.

KEY POINTS

- Cool slowly for larger, better-formed crystals.
- Do not disturb the solution while cooling.
- Crystals form from the remaining mother liquor as the solution cools.
- Collected crystals should be surface-dried, not described as fully dry or proven pure.

PARTICLE VIEW



TOP TIP: Crystals often start to form at the edges as the solution cools — this is normal.

WHY THESE STEPS MATTER — Filtration removes unreacted solid → Controlled evaporation concentrates the solution → Crystallisation produces hydrated crystals on cooling → **RELATIVELY PURE, SURFACE-DRY HYDRATED CRYSTALS**

QUANTITATIVE CHEMISTRY — PERCENTAGE YIELD

Worked example for making hydrated copper(II) sulfate crystals

1. Measure the actual mass of crystals

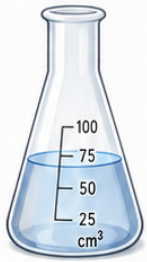
Mass of empty labelled watch glass = m_1 g

Mass of watch glass + surface-dry crystals = m_2 g

Actual mass of crystals = $m_2 - m_1$

ⓘ Use surface-dry hydrated crystals.

2. Calculate the amount of sulfuric acid



$$n = c \times V$$

$c = 1.0 \text{ mol dm}^{-3}$

$V = 40 \text{ cm}^3 = 0.040 \text{ dm}^3$

$n(H_2SO_4) = 1.0 \times 0.040 = 0.040 \text{ mol}$

ⓘ Always convert cm^3 to dm^3 before using $n = c \times V$.

3. Use the reacting ratio

$$CuO_{(s)} + H_2SO_{4(aq)} \rightarrow CuSO_{4(aq)} + H_2O_{(l)}$$

The reacting ratio is 1 : 1

Copper(II) oxide is added in excess, so sulfuric acid is the limiting reactant.

$n(CuSO_4 \cdot 5H_2O) = 0.040$ mol

ⓘ The blue crystals are hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$.

4. Calculate the theoretical mass

$M_r(CuSO_4 \cdot 5H_2O) = 249.7$

Theoretical mass = $n \times M_r$

Theoretical mass = 0.040×249.7

Theoretical mass ≈ 10.0 g

5. Calculate percentage yield

$$\text{Percentage yield} = \left(\frac{\text{actual mass}}{\text{theoretical mass}}\right) \times 100$$

Example actual mass = 7.5 g

$$\text{Percentage yield} = \left(\frac{7.5}{10.0}\right) \times 100 = 75\%$$

Percentage yield = 75%

6. What do the results mean?

Yield below 100% may be caused by:

- crystals left in the mother liquor
- transfer losses
- spitting during heating
- excessive washing
- incomplete crystallisation

Apparent yield above 100% may be caused by:

- wet crystals
- contamination
- calculation error
- using the wrong formula mass

⚠ Use $CuSO_4 \cdot 5H_2O$, not $CuSO_4$, when calculating the mass of the blue hydrated crystals.

KEY TAKEAWAY

For 40 cm^3 of 1.0 mol dm^{-3} H_2SO_4, the maximum theoretical yield of $CuSO_4 \cdot 5H_2O$ is about 10.0 g. Percentage yield compares the actual mass collected with this theoretical maximum.

Sources of Error & Improvements

Source of error	Likely effect	Improvement
Too little copper(II) oxide added	Acid may remain in the filtrate and contaminate the product	Continue adding small portions until black solid remains after thorough stirring
CuO added too rapidly to hot acid	Frothing, splashing and loss of mixture	Turn off the burner and add small portions with stirring
Mixture filtered while still very hot	Increased burn risk and potentially poor handling	Allow the beaker and mixture to cool before filtration
Torn or poorly fitted filter paper	Black particles pass into the filtrate	Use intact, correctly fitted paper and re-filter a contaminated filtrate
Solution lost during transfer	Actual and percentage yield decrease	Pour carefully and rinse the reaction beaker with only a small quantity of water
Filtrate heated too strongly	Spitting and product loss	Use controlled heating in a water bath or approved electric heater
Solution evaporated too far	Crust formation, spitting or dehydration of the product	Stop when a cooled test drop crystallises or first crystals appear
Too much or warm wash water used	Product dissolves and yield decreases	Use only a very small amount of cold distilled water
Crystals not surface-dry	Measured mass is too high	Blot gently and allow surface moisture to evaporate before weighing
Crystals left in solution	Yield is lower than it could be	Collect crystals carefully and allow sufficient crystallisation time

Reliability

Reliability concerns whether repeated results are consistent.

Reliability can be assessed by:

- repeating the preparation using the same method and quantities;
- calculating the actual or percentage yield for each repeat;
- comparing the spread of the results;
- identifying anomalous results;
- calculating a mean when the results are sufficiently consistent.

Using clean apparatus, accurate measurements and a standardised heating method improves the quality and comparability of the results.

Excessive heating can remove water of crystallisation from blue hydrated copper(II) sulfate, changing its colour and measured mass. More severe heating can cause further decomposition.

Method Suitability and Product Quality

The method is suitable for preparing relatively pure hydrated copper(II) sulfate crystals when:

- copper(II) oxide is added until a persistent excess remains;
- the Bunsen burner is turned off before copper(II) oxide is added;
- the excess solid is completely removed by filtration;
- the filtrate is concentrated without vigorous boiling or spitting;
- the solution is not evaporated to dryness;
- the concentrated solution is allowed to cool slowly and undisturbed;
- crystals are separated from the solution and surface-dried;
- transfer and washing losses are minimised.

The formation of blue crystals is consistent with hydrated copper (II) sulfate, but colour and appearance alone do not prove that the product is completely pure.

Conclusion

A good conclusion should include:

- whether hydrated copper(II) sulfate crystals were produced;
- the observations that support this conclusion;
- why copper(II) oxide was added in excess;
- the purpose of filtration;
- how concentration and cooling produced crystals;
- actual and percentage yield, if measured;
- likely causes of product loss or contamination.

GCSE Practical Skills and Specification Alignment

This guide uses an AQA-aligned heating sequence: a Bunsen burner is used to warm the acid and a water bath or electric heater is used to concentrate the filtrate. AQA identifies this as Required Practical Activity 1. Pearson Edexcel identifies preparation of pure, dry hydrated copper sulfate crystals from copper oxide, including use of a water bath, as Core Practical 3.17. Teachers should check the terminology and precise method required by their examination board.

Students develop:

- accurate measurement of liquid volume;
- safe use of a Bunsen burner;
- safe use of a water bath or electric heater;
- controlled mixing of a solid and a liquid;
- recognition of a persistent excess reactant;
- correct filtration technique;
- identification of residue and filtrate;
- evaporation and crystallisation;
- safe handling of hot apparatus;
- recording qualitative and quantitative observations;
- use of balanced equations and state symbols;
- calculation of actual and percentage yield;
- evaluation of product loss and contamination.

Common Misconceptions

Misconception	Correct explanation
The salt is made during evaporation	Dissolved copper(II) sulfate forms during neutralisation. Evaporation only concentrates the solution; cooling produces crystals
The excess copper(II) oxide will contaminate the crystals	Correct filtration removes excess CuO. It contaminates the product only if filtration is poor
Bigger crystals mean a greater yield	Crystal size and total yield are different measurements. A sample can contain many small crystals but still have a large total mass
All the water is produced by the reaction	Only a relatively small amount of water is produced chemically. Most of the water is the solvent already present in the dilute acid
Drying removes all the water	Surface drying removes mother liquor and surface water. The blue crystals retain water of crystallisation
Evaporation should continue until no liquid remains	The solution should only be concentrated. Evaporating to dryness can cause spitting and alter the hydrated product
Blue crystals prove the product is pure	The colour is consistent with hydrated copper(II) sulfate but does not prove complete purity
Copper(II) sulfate exists as molecules in solution	The solution contains dispersed $Cu^{2+}(aq)$ and $SO_4^{2-}(aq)$ ions

Examiner Advice

Measure a known volume of acid

Provides a known starting quantity and makes the method repeatable.

Warm the acid

Increases the rate at which copper(II) oxide reacts.

Turn off the Bunsen burner before adding CuO

Reduces the risk of splashing or frothing while solid is being added and prevents unnecessary heating.

Add copper(II) oxide in small portions

Keeps the reaction controlled and makes it easier to identify when excess solid remains.

Use excess insoluble base

Ensures that all the sulfuric acid has reacted.

Filter the mixture

Removes the excess insoluble copper(II) oxide. The black solid is the residue and the blue solution is the filtrate.

Concentrate the filtrate

Removes some solvent so that crystals can form when the solution cools.

Use a water bath or electric heater

Provides controlled heating and reduces the risk of vigorous boiling,

Do not evaporate to dryness

The required product is obtained by crystallisation from a concentrated solution.

Cool slowly and leave undisturbed

Allows hydrated crystals to grow.

Use only a small amount of cold wash water

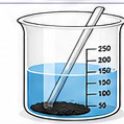
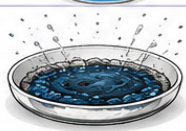
Removes adhering mother liquor while limiting dissolution of the product.

Surface-dry before weighing

Removes surface liquid that would otherwise make the measured mass too high.

COMMON MISTAKES → CONSEQUENCES → FIX

Avoid these pitfalls to obtain hydrated copper(II) sulfate crystals with good yield and quality.

MISTAKE	CONSEQUENCE	HOW TO FIX
Adding copper(II) oxide while the Bunsen burner is still on Solid is added while the mixture is still being heated. 	Increased risk of frothing, splashing and loss of hot acidic mixture. 	Turn off the Bunsen burner and close the gas tap before adding any solid. 
Not adding enough insoluble base The acid is not fully neutralised. 	Acid remains in solution. Crystals may be contaminated or may not form properly. 	Add small portions with stirring until black solid remains after thorough stirring. 
Not filtering properly Black particles pass through the filter paper. 	Solid contamination remains in the solution and can end up in the crystals. 	Use intact, correctly fitted filter paper. If black particles have passed through, re-filter the blue filtrate using fresh filter paper. 
Heating too strongly or too far The solution is concentrated too aggressively. 	Vigorous heating may cause spitting and product loss. Heating too far may also remove water of crystallisation or produce a solid crust. 	Concentrate the solution gently using a water bath or approved electric heater. Stop before the solution evaporates to dryness. 
Disturbing the solution while cooling Moving the crystallising dish or touching the solution. 	Rapid or disturbed cooling generally produces many smaller or irregular crystals. 	Allow the solution to cool slowly and undisturbed. 
Not washing the crystals The crystals are collected but not rinsed. 	Mother liquor and soluble surface impurities remain on the crystals. 	Rinse rapidly with a very small amount of cold distilled water. 
Using too much or warm wash water The wash step dissolves too much product. 	Some hydrated copper(II) sulfate dissolves and the yield decreases. 	Use the smallest practical volume of cold distilled water. 

TOP TIP: Work carefully at each stage and use gentle, controlled technique for the best crystals and yield.

SOLUBLE vs INSOLUBLE BASES
WHY EXCESS SOLID WORKS

Different bases require different methods to prepare a salt.

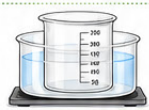
INSOLUBLE BASES
Examples: copper(II) oxide, magnesium oxide, copper(II) carbonate

Why excess can be used
An insoluble base does not all dissolve. Excess unreacted solid can therefore be separated by filtration.

HOW IT WORKS

1. Warm the acid.

2. Turn off the heat.



3. Add the insoluble base in small portions until some remains.

4. Filter off the excess solid.

5. Concentrate the salt solution.

6. Cool, collect and surface-dry the crystals.

EXAMPLE REACTION

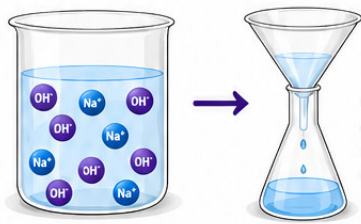
$$CuO\ (s) + H_2SO_4\ (aq) \rightarrow CuSO_4\ (aq) + H_2O\ (l)$$

WHY THIS ROUTE WORKS
- Excess solid can be removed by filtration.
- A clear salt solution is obtained before concentration.
- This is the route used here to prepare copper(II) sulfate.

SOLUBLE BASES OR ALKALIS
Examples: sodium hydroxide solution, potassium hydroxide solution

Why excess must not be used
Both the alkali and the salt remain dissolved in water. Any excess alkali cannot be removed by filtration and would contaminate the salt solution.

BOTH DISSOLVED – CANNOT BE SEPARATED BY FILTRATION



TITRATION METHOD

1. Use an indicator to carry out a titration and determine the reacting volumes.

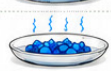
2. Obtain concordant results.

3. Repeat using the determined volumes of acid and alkali without indicator.

4. Concentrate the resulting salt solution.

5. Cool to crystallise the salt.

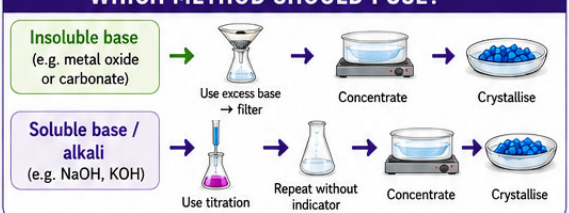
6. Collect and dry the crystals.



The second preparation is repeated without indicator because indicator would contaminate the product.

KEY POINT
This is a valid GCSE method for preparing salts from soluble acid and alkali reactants.

WHICH METHOD SHOULD I USE?



KEY TAKEAWAY

Excess works only with insoluble bases because unreacted solid can be filtered away.

This guide uses the insoluble-base route to prepare copper(II) sulfate. Other soluble salts may require a titration route.

Troubleshooting Guide

Problem	Likely cause	Corrective action
No crystals after cooling	Solution was not concentrated enough	Return the mother liquor to the evaporating basin and concentrate it gently in the water bath. Test a cooled drop before stopping
Crystals appeared during heating	Solution has become highly concentrated	Stop heating immediately and allow the solution to cool
Black powder in the filtrate	Filter paper was torn, overfilled or poorly fitted	Re-filter the blue liquid through fresh, correctly fitted filter paper
Black specks in the final crystals	Excess CuO passed through the filter	Redissolve the product, re-filter and recrystallise, or repeat the preparation
Only very small crystals form	Cooling was too rapid or the dish was disturbed	Allow slower, undisturbed cooling using the same starting concentration
Solution remains blue after crystals form	Some product remains dissolved in the mother liquor	This is expected. Further careful concentration may recover more product but can reduce purity
Green, brown or unusual-coloured product	Contamination, incorrect reagent or dirty apparatus	Do not treat the current product as correct. Check reagent labels, apparatus and procedure before repeating
Low yield	Spillage, transfer loss, excessive washing, incomplete crystallisation or crystals left in mother liquor	Review each stage; transfer carefully, minimise wash volume and allow sufficient crystallisation time
Apparent yield above 100%	Crystals are wet or contaminated, or the wrong formula mass was used	Surface-dry the crystals, check for black particles and recalculate using $CuSO_4 \cdot 5H_2O$
Solution spits during concentration	Heating is too vigorous	Reduce heating immediately and use the approved water-bath arrangement

Common Exam Questions

1. Why is copper(II) oxide added until some black solid remains?

Answer: To ensure that all the sulfuric acid has reacted. The remaining black solid shows that copper(II) oxide is in excess.

2. Why is the Bunsen burner turned off before copper(II) oxide is added?

Answer: To reduce the risk of frothing or splashing while solid is being added and to prevent unnecessary heating.

3. Why is copper metal not used with dilute sulfuric acid?

Answer: Copper is below hydrogen in the reactivity series and does not react with dilute sulfuric acid, whereas copper(II) oxide is a base and neutralises the acid.

4. What is the residue in this practical?

Answer: Excess unreacted copper(II) oxide.

5. What is the filtrate?

Answer: The clear blue copper(II) sulfate solution that passes through the filter paper.

6. Why is the filtrate concentrated rather than evaporated to dryness?

Answer: Concentration produces a solution from which hydrated crystals can form on cooling. Evaporating to dryness may cause spitting and alter the hydrated product.

Common Exam Questions

7. Why is a water bath or electric heater used?

Answer: It provides more controlled heating and reduces the risk of vigorous boiling, spitting and overheating.

8. Why is slow cooling recommended?

Answer: Slow, undisturbed cooling generally produces larger, better-formed crystals.

9. Why should only a small amount of cold water be used to wash the crystals?

Answer: Cold water removes adhering mother liquor while limiting dissolution of the product.

10. Why are the crystals surface-dried before weighing?

Answer: Adhering mother liquor and surface water would make the measured mass artificially high.

11. Write the balanced equation with state symbols.

Answer: $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_{4(}aq) + H_2O(l)$

12. A student obtains 7.5 g of crystals when the theoretical yield is 10.0 g. Calculate the percentage yield.

Answer: $(7.5 \div 10.0) \times 100 = 75\%$

Advanced Evaluation Points (Grade 8–9)

Students aiming for the highest grades should explain:

- why a persistent excess of CuO shows that the acid has reacted completely;
- why excess CuO must be removed before concentration;
- why vigorous heating can reduce yield through spitting;
- why some product remains dissolved in the mother liquor;
- why excessive wash water reduces yield;
- why wet crystals can give an apparent yield above 100%;
- why rapid concentration or cooling can produce many small crystals and retain pockets of mother liquor between them;
- why appearance alone cannot confirm complete purity;
- why the relative formula mass of $CuSO_4 \cdot 5H_2O$ must be used for the blue hydrated crystals;
- how actual and percentage yield are calculated.

Writing a Good Scientific Conclusion

A strong conclusion should:

- answer the aim directly;
- use observations and measurements as evidence;
- include actual and percentage yield where available;
- explain the chemistry rather than only list the method;
- distinguish product identity from proven purity;
- identify likely losses or contamination;
- suggest improvements linked to those limitations.

Advanced Evaluation Points (Grade 8–9)

Extension Investigation — Effect of Cooling Rate on Crystal Size

Independent variable: Cooling condition, such as insulated cooling, room-temperature cooling or ice-bath cooling.

Dependent variable: Mean longest dimension of a defined number of crystals, measured using a millimetre grid or suitable magnifier.

Control variables:

- volume and concentration of the copper(II) sulfate solution;
- concentration endpoint before cooling;
- starting temperature;
- crystallising vessel;
- total cooling time;
- degree of disturbance;
- method used to collect and dry the crystals.

Reliability: Repeat each cooling condition and calculate the mean crystal dimension.

Safety: Move hot solutions using the approved equipment and place them only in designated cooling areas.

Real-World Applications

- Fertilisers – Many plant fertilisers are manufactured as salts, such as ammonium sulfate.
- Medicines – Pharmaceutical companies produce carefully controlled purity salts for use in drugs and medical treatments.
- Water Treatment – Salts such as aluminium sulfate are used to remove impurities from drinking water.
- Food Industry – Common table salt and many food preservatives are salts produced through controlled chemical processes.
- Batteries – Many modern batteries contain metal salts that help store and transfer electrical energy.
- Chemical Manufacturing – Crystallisation is widely used to purify chemicals produced on an industrial scale.

Teacher / Technician Preparation Notes

Risk Assessment: Model Risk-Control Information

This table does not replace the school's own risk assessment. The final assessment must use the exact concentrations, quantities, supplier safety data sheets, current CLEAPSS or equivalent guidance, student experience, equipment and local emergency procedures.

Hazard or activity	Possible harm	Required control measures	Emergency or corrective action
1.0 mol dm^{-3} sulfuric acid	Skin or eye irritation; damage from splashes	Wear splash-resistant eye protection; use small quantities; measure below eye level; keep container stoppered when not in use	Alert the teacher immediately; irrigate affected skin or eyes with plenty of water and follow local emergency procedures
Copper(II) oxide powder	Dust may irritate eyes or skin and may be harmful if inhaled or swallowed	Avoid raising dust; transfer with a spatula; keep container closed; do not touch or taste; wash hands after use	Stop work, alert the teacher and follow the product SDS and local spill procedure
Adding CuO to warm acid	Frothing or splashing of hot acidic mixture	Turn off the Bunsen burner first; add small portions; stir carefully; do not lean over the beaker	Move away from the splash, alert the teacher and follow local exposure procedures
Copper(II) sulfate solution and crystals	Eye or skin exposure; harmful if swallowed; environmental contamination	Wear eye protection; avoid contact; no eating or drinking; wash hands; keep product in labelled vessels	Clean exposures and spills according to the SDS and school procedure
Bunsen burner and gas supply	Burns, fire or ignition of hair and clothing	Check hose and connection; use a heatproof mat; tie hair back; secure ties; keep flammables away; close gas tap after warming	Turn off the gas if safe; alert the teacher; follow the laboratory fire procedure
Hot acid, water bath and salt solution	Burns or scalds	Use controlled heating; do not overfill; keep apparatus stable; allow cooling before filtration; use suitable tongs for hot basins	Cool minor thermal exposure under running water and alert the teacher; follow school first-aid procedures
Evaporating solution	Spitting, splashing or boiling dry	Use a water bath or approved electric heater; do not leave unattended; stop at the concentration endpoint	Turn off heat, stand back and allow apparatus to cool
Glassware	Breakage and cuts	Inspect before use; keep away from bench edges; support funnel securely; do not force glassware	Do not pick up broken glass by hand; inform the teacher and use the approved brush and container
Copper-containing waste	Environmental harm	Collect copper-containing solution, crystals, CuO residue and contaminated filter paper in labelled waste streams; follow local disposal procedures	Contain spills and inform the technician or teacher

Teacher / Technician Preparation Notes

Technician Tips for High Success Rates

- Prepare and label sulfuric acid at the validated concentration. For the AQA-aligned method, provide 40 cm^3 of 1.0 mol dm^{-3} sulfuric acid per group.
- Provide approximately 4 g of copper(II) oxide per group in a suitable labelled container. Students should add it in portions rather than use the whole quantity at once.
- Keep copper(II) oxide containers closed when not in use and avoid handling that raises dust.
- Check Bunsen burners, hoses, gas taps, tripods and gauzes before the lesson.
- Ensure every tripod has three stable legs and every gauze is correctly centred.
- Provide a 250 cm^3 beaker or approved apparatus for each water bath.
- Provide tongs suitable for the evaporating basins being used.
- Pre-fold or pre-cut filter papers for classes requiring additional support.
- Check that funnels can be supported securely over the receiving flasks.
- Provide labelled crystallising dishes or watch glasses so samples can be stored until the following lesson.
- Prepare a clearly labelled cooling area where hot apparatus can remain undisturbed.
- Trial the method before teaching it to confirm the acid quantity, amount of CuO required and concentration endpoint.
- Use a separate cool white tile for the test-drop endpoint; do not place ordinary paper under hot apparatus.
- Provide labelled waste containers for copper-containing liquids, solids and filter papers.
- Keep spare pre-filtered copper(II) sulfate solution available for groups that lose their sample.
- Prepare a good-quality sample of hydrated crystals so students can compare their result with the expected appearance.
- Ensure distilled-water wash bottles are clearly labelled and dispense only a small stream.
- Plan for overnight or between-lesson crystallisation rather than assuming that developed crystals will form within a few minutes.

Teacher / Technician Preparation Notes

Before the Lesson

- Confirm the examination-board method and departmental risk assessment.
- Check the current supplier safety data sheets.
- Prepare and label sulfuric acid at the stated concentration.
- Dispense the required quantities of copper(II) oxide while minimising dust.
- Check Bunsen burners, gas hoses, three-legged tripods and gauzes.
- Prepare the water-bath equipment and suitable tongs.
- Set out clean filter funnels, correctly sized filter papers and conical flasks.
- Label crystallising dishes or provide labels for student samples.
- Establish a safe, undisturbed cooling area.
- Provide labelled copper-containing waste containers.
- Prepare spare filtrate and an example of the expected hydrated crystals.
- Confirm how samples will be stored between lessons.

Teacher Demonstration Point

Before students start, demonstrate:

- Recognising excess solid.
- Correct filtration technique.
- Judging when enough water has evaporated.
- Proper crystal formation during cooling.

Students often struggle most with recognising the correct stage to stop heating.

Teacher / Technician Preparation Notes

Suggested Lesson Timing: Two-session model

Lesson stage	Approximate time
Starter and learning objectives	5 min
Safety briefing and teacher demonstration	10 min
Measure and warm acid	5 min
Add copper(II) oxide to excess	8–10 min
Cool sufficiently and filter	10 min
Concentrate filtrate using water bath	10–12 min
Transfer, label and place in cooling area	5 min
Crystallisation between lessons	Preferably overnight
Observe and collect crystals in next lesson	10 min
Surface-dry, weigh and calculate yield	10–15 min
Evaluation and plenary	10 min

Teacher / Technician Preparation Notes

Teacher Assessment Opportunities

- Safe working: Wears eye protection, secures hair and tie, keeps the bench clear and follows chemical-handling instructions.
- Heating technique: Uses a stable three-legged tripod, warms the acid without boiling and turns off the gas before adding CuO.
- Reaction technique: Adds CuO gradually, stirs after each addition and identifies persistent excess correctly.
- Filtration: Fits the filter paper correctly, supports the funnel and distinguishes the residue from the filtrate.
- Concentration: Uses the water bath correctly and stops before the solution evaporates to dryness.
- Hot apparatus: Uses appropriate tongs or allows apparatus to cool before handling.
- Crystallisation: Labels the sample and leaves it undisturbed.
- Recording: Records concentration, volume, observations, mass and units clearly.
- Chemical understanding: Writes the equation with state symbols and explains the role of excess CuO.
- Quantitative chemistry: Calculates actual mass, theoretical mass and percentage yield.

Suggested Plenary

Question	Expected answer
Why is the acid warmed?	To increase the rate of reaction
Why is the Bunsen burner turned off before CuO is added?	To reduce splashing or frothing and prevent unnecessary heating
Why is excess copper(II) oxide added?	To ensure all the sulfuric acid reacts
What is the residue?	Excess unreacted copper(II) oxide
What is the filtrate?	The clear blue copper(II) sulfate solution
Why is the filtrate concentrated?	So crystals can form when the concentrated solution cools
Why is the solution not evaporated to dryness?	Vigorous or excessive heating can cause spitting, product loss and alteration of the hydrated product
Why are the crystals surface-dried?	To remove adhering mother liquor and surface water before weighing
What is the formula of the hydrated crystals?	$CuSO_4 \cdot 5H_2O$
What type of reaction occurs?	Neutralisation

Examiner Advice Summary

Students lose marks by:

- saying that the acid “disappears” rather than reacts;
- failing to state that excess solid ensures complete neutralisation;
- saying evaporation makes the salt;
- confusing concentration with boiling to dryness;
- saying filtration removes the dissolved salt;
- confusing the residue and the filtrate;
- saying drying removes the water of crystallisation;
- claiming that blue colour proves complete purity;
- omitting state symbols;
- using $CuSO_4$ rather than $CuSO_4 \cdot 5H_2O$ in a theoretical-yield calculation for the blue hydrated crystals;
- giving an improvement without explaining how it affects yield, accuracy or product quality.