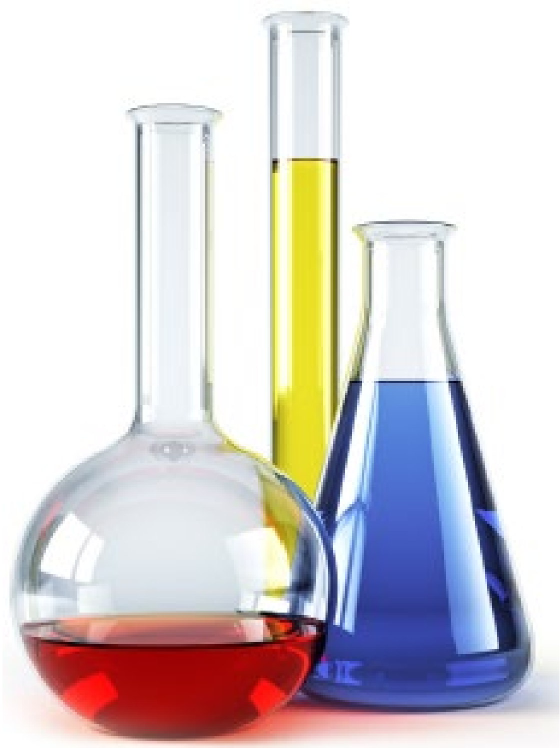
Cambridge Assessment International Education

Skills Pack

Identifying positive metal ions

Cambridge International AS & A Level Chemistry 9701



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Cambridge Pathway

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Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Skills Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 3 (Advanced Practical Skills) or Paper 5 (Planning, Analysis and Evaluation).

This is one of a range of *Skills Packs* and each pack is based on one experiment. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson reinforces the key concepts, relevant skills, knowledge and understanding linked to the experiment.

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Planning lesson (1 hour*)
This lesson focuses on planning an experiment. It ends with a demonstration video of the experiment.

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Lab lesson (1 hour*)
This lesson focuses on carrying out the experiment including the collection and recording of observations, measurements and estimates.

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Debriefing lesson (1 hour*)
This lesson focuses on the analysis and interpretation of data. This includes making conclusions, evaluating methods and the quality of data and how improvements could be made.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack you will find lesson plans, worksheets and teacher resource sheets.

Experiment: Identifying positive metal ions

This *Skills Pack* focuses on identifying positive metal ions.

Qualitative analysis is a widely used method for identifying different substances in samples, for example from river water. In this experiment, you will identify different positive metal ions based on the colour and solubility of precipitates formed in alkaline conditions.

This experiment has links to the following syllabus content (see syllabus for detail):

- Paper 3 Advanced Practical Skills

The experiment covers the following experimental skills, as listed in **AO3: Experimental skills and investigations:**

- plan experiments and investigations
- collect, record and present observations, measurements and estimates
- analyse and interpret data to reach conclusions
- evaluate methods and quality of data and suggest improvements.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 2.3 Formulas

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • Worksheets A, B, C • Equipment as outlined in the notes

Learning objectives	By the end of the lesson: • ***All learners should be able to collect appropriate experimental observations relating to the identification of metal ions.*** • ***Most learners should be able correctly predict the identify of metal ions based on model scientific data.*** • ***Some learners should be able to make connections between their observations and the chemistry of the different metals.***

Timings	Activity
10	**Starter/Introduction** • Hand out WS A • In pairs, students work through the table, recalling the formulae or name of various metal ions and substances involved in metal ion precipitation. • Check their answers and correct as necessary.
30-40	**Main lesson** • Distribute worksheets B and C • Arrange the learners into group of two. • Complete the practical activity **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate.
10-20	**Plenary** • Check student observations against model data. • Ask the students to complete the questions then check their answers. • In remaining time, have the students self or peer quiz each other on the expected observations of the precipitation reactions.

1

Teacher notes

Watch the identifying positive ions (teacher version) and read these notes.

Each group will require:

- Instruction sheet inside plastic wallet (see last page of this document)
- Dropper bottles of:
  - 0.1 M aluminium chloride
  - 0.1 M barium chloride
  - 0.1 M calcium chloride
  - 0.1 M chromium(III) chloride
  - 0.1 M copper sulfate (WARNING: irritant)
  - 0.1 M iron(II) sulfate, acidified
  - 0.1 M iron(III) nitrate
  - 0.1 M magnesium sulfate
  - 0.1 M manganese(II) sulfate
  - 0.1 M zinc sulfate (WARNING: irritant)
  - 0.4 M sodium hydroxide (WARNING: irritant)
  - 1 M ammonia (freshly prepared) (WARNING: irritant)
- Paper towels
- Bucket of water

Safety

The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

- Wear eye protection
- Follow the disposal instruction carefully
- Wash your hands after completing the reaction
- Rinse hands thoroughly if there is any contact with any precipitates/solutions.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Substance	Hazard	First aid
0.1 M copper sulfate (WARNING: irritant)		**In the eye:** flood the eye with gently-running tap water for at least 10 minutes. See a doctor. **Swallowed:** wash out the mouth with water. Do not induce vomiting. Sips of water may help cool the throat and help keep the airway open. See a doctor. **Spilt on the skin or clothing:** remove

Substance	Hazard	First aid
		contaminated clothing and rinse it. Wash off the skin with plenty of water.
0.1 M zinc sulfate (WARNING: irritant)		
0.4 M sodium hydroxide (WARNING: irritant)		
1 M ammonia (freshly prepared) (WARNING: irritant)		

Experiment set-up

Metal ion and colour	Metal and water	Metal + 1 drop NaOH	Metal and 5 drops NaOH	Metal and 1 drop NH_3	Metal and 5 drops NH_3
Al^{3+}					
Ba^{2+}					
Ca^{2+}					
Cr^{3+}					
Cu^{2+}					
Fe^{2+}					
Fe^{3+}					
Mg^{2+}					
Mn^{2+}					
Zn^{2+}					

Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners.

Before you begin

Plan how you will group your learners during the experiment session.

Think about:

- the number of groups you will need (group size 2–4 learners)
- the amount of equipment/chemicals required

Experiment

Walk around the learners during the experiment in case they encounter any difficulties.

Step #	Method	Notes
Before	Check that learners have the materials and apparatus in front of them.	Pre-sorting the equipment into individual group boxes can make distribution and collection of equipment more efficient
Before	Check that the learns have WS C & D.	
Before	(Re)discuss the health and safety aspects of the experiment.	
1	Place the practical instruction sheet inside the plastic wallet.	
2	Place the wallet flat on your work surface.	A flat and level surface is important to ensure the drops don't run together. If such a surface isn't possible, the practical can be carried out in multi-well plates.
3	Add two drops of each metal ion solution from the appropriate dropper bottles separately to the appropriate reaction squares.	Learners may need practice producing individual drops from the dropper bottles. As required, have the students practice making lines of drops from a dropper bottle containing water.
4	Place one drop of water from the appropriate dropper bottle into the first column of the metal ion solution drops.	

5	Observe and record the colour of the solutions in your results table (WS D)	If you have colour-blind students, consider producing a print out of the expected colours with the colours labelled.
6	Place one drop of sodium hydroxide from the appropriate dropper bottle into the first column of the metal ion solution drops.	
7	Observe and record the colour of any precipitate formed.	
8	Place five drops of sodium hydroxide from the appropriate dropper bottle into the first column of the metal ion solution drops.	Learners need to observe the drops carefully to see the precipitate dissolving. If necessary, learners can stir the drops with wooden splints (or similar) to encourage mixing.
9	Observe and record whether the precipitates dissolved with excess sodium hydroxide.	
10	Place one drop of ammonia from the appropriate dropper bottle into the first column of the metal ion solution drops.	Warn learners not to get too close to the drops with ammonia given the hazardous nature of the gas.
11	Observe and record the colour of any precipitate formed.	
12	Place five drops of ammonia from the appropriate dropper bottle into the first column of the metal ion solution drops.	
13	Observe and record the whether the precipitates dissolved with excess ammonia and/or the colour change of the solution.	
14	Wipe up the drops with paper towels and place the towels in a bucket of water.	Placing the towels in bucket of water dilutes any heavy metals down to concentrations appropriate for disposal via the foul water drain.
15	Remove the practical instruction sheet and rinse the plastic wallet in water.	

Clean-up

After the experiment learners should:

- Tidy their workspace

- Ensure any spillages have been mopped up
- Return all equipment and unused chemicals to you.
- return all equipment and any unused chemicals to you.

Lab lesson: Option 2 – virtual experiment

Resources	• Virtual experiment video for the identification of positive ions video • Worksheet D

Learning objectives	By the end of the lesson: • ***All learners should be able to collect appropriate experimental observations relating to the identification of metal ions.*** • ***Most learners should be able correctly predict the identify of metal ions based on model scientific data.*** • ***Some learners should be able to make connections between their observations and the chemistry of the different metals.***

Timings	Activity
10	**Starter/Introduction** • Hand out WS A • In pairs, students work through the table, recalling the formulae or name of various metal ions and substances involved in metal ion precipitation. • Check their answers and correct as necessary.
30-40	**Main lesson** • Show the *Virtual Experiment video* from start to finish once though without stopping. • Give the learners a copy of WS D, allowing them time to look through and understand the results table and questions. They should not write anything at this stage. Show the video again to the learners, stopping the video as necessary. Learners then work in pairs to complete the sheet, helping each other when required. • Project the answer sheet and go over the answers, allowing them time to correct any mistakes. Ask learners to verbally feedback on their observations and compare & contrast these with the expected observations.
10-20	**Plenary** • • Check student observations against model data. • Ask the students to complete the questions then check their answers. • In remaining time, have the students self or peer quiz each other on the expected observations of the precipitation reactions.

Debriefing lesson: Consolidating the underlying chemistry

Resources	• WS E • Images of water analysis, DNA extraction, crystallisation of organic substances

Learning objectives	By the end of the lesson: • All learners should be able to competently answer questions related to use of precipitation for analysis of substances.

Timings	Activity
10	**Starter/Introduction** Ask the learners to consider the images and identify a common theme. Following their discussion if precipitation has not been mentioned give the answer. Then discuss the importance of precipitation in terms of identifying substances in solution (such as the analysis of water for the presence of toxic heavy metals), in extracting substances from mixtures (as in DNA extraction) and purification of synthesised compounds (such as crystallisation of synthesis targets such as aspirin).
40	**Main lesson** • Give out WS E and ask learners to work in pairs through the questions. • If they find themselves struggling with any questions, encourage them to consult their textbook, then with another pair of learners before asking the teacher. • Work through the answers to the questions, modelling your thinking to help students understand the mental processes you use when tackling questions. Give the students time to self and peer quiz each other on the expected outcomes of the precipitation tests.
10	**Plenary** Give the students a 10 point quiz on the colours and solubility of the positive ion precipitates with sodium hydroxide and ammonia.

Worksheets and answers

	Worksheet	Answers
For use in *Lab lesson*:		
A: [Starter]	**x**	**x**
B: Experimental set-up and method	**x**	**x**
C: Practical sheet for placing in plastic wallet	**x**	**x**
For use in *Debriefing lesson*		
D: Results and evaluation	**x**	**x**
E: Some questions	**x**	**x**

Worksheet A: Starter

Use this worksheet with Lab Lesson (option 1 or 2)

Instructions

1. Complete the table below with either the name or the formulae of the substances.

Name	Formula
Aluminium	
Barium	
	Ca^{2+}
	Cr^{3+}
Copper(II)	
Iron(II)	
	Fe^{3+}
Magnesium	
	Mn^{2+}
	Zn^{2+}
	NaOH
Ammonia	

2. Write a word equation for the reaction between copper(II)
3. sulfate(VI) solution and sodium hydroxide solution.
4. Write a symbol equation for the reaction between copper(II) sulfate(VI) solution and sodium hydroxide solution.
5. Explain why both sodium hydroxide and ammonia solutions are alkaline.

Worksheet B: Experimental set-up and method

Instructions

Method

1. Place the practical instruction sheet inside the plastic wallet.
2. Place the wallet flat on your work surface.
3. Add two drops of each metal ion solution from the appropriate dropper bottles separately to the appropriate reaction squares.
4. Place one drop of water from the appropriate dropper bottle into the first column of the metal ion solution drops.
5. Observe and record the colour of the solutions in your results table (WS D)
6. Place one drop of sodium hydroxide from the appropriate dropper bottle into the first column of the metal ion solution drops.
7. Observe and record the colour of any precipitate formed.
8. Place five drops of sodium hydroxide from the appropriate dropper bottle into the first column of the metal ion solution drops.
9. Observe and record whether the precipitates dissolved with excess sodium hydroxide.
10. Place one drop of ammonia from the appropriate dropper bottle into the first column of the metal ion solution drops.
11. Observe and record the colour of any precipitate formed.
12. Place five drops of ammonia from the appropriate dropper bottle into the first column of the metal ion solution drops.
13. Observe and record the whether the precipitates dissolved with excess ammonia and/or the colour change of the solution.
14. Wipe up the drops with paper towels and place the towels in a bucket of water.
15. Rinse the plastic wallet in water.

Worksheet C: Practical sheet for placing in plastic wallet

Metal ion and colour	Metal and water	Metal + 1 drop NaOH	Metal and 5 drops NaOH	Metal and 1 drop NH_3	Metal and 5 drops NH_3
Al^{3+}					
Ba^{2+}					
Ca^{2+}					
Cr^{3+}					
Cu^{2+}					
Fe^{2+}					
Fe^{3+}					
Mg^{2+}					
Mn^{2+}					
Zn^{2+}					

Worksheet D: Results and evaluation

Instructions

Metal ion and colour	Colour of solution	Colour of precipitate in NaOH	Precipitate soluble in excess NaOH?	Colour of precipitate in NH_3	Precipitate soluble in excess NH_3?
Al^{3+}					
Ba^{2+}					
Ca^{2+}					
Cr^{3+} / green or purple					
Cu^{2+}					
Fe^{2+}					
Fe^{3+}					
Mg^{2+}					
Mn^{2+}					
Zn^{2+}					

1. State which ions formed white precipitates in the presence of sodium hydroxide.
2. What do these ions have in common?
3. State which ions formed coloured precipitates in the presence of sodium hydroxide.
4. What do these ions have in common?

Worksheet E: Some questions

1. A metal nitrate solution is investigated by a student. Sodium hydroxide solution causes a white precipitate to appear. Which metal ions could be present?
2. The student continues to add sodium hydroxide solution, and the white precipitate remains. Which ions could be present?
3. The student added ammonia to some of the original solution and a white precipitate appeared. Which metal ion could be present?
4. If ammonia cause a white precipitate to appear, which metal ions could be present?
5. How would the student distinguish these between the two metal ions from Q4?
6. The student was investigating a pale green solution to determine which metal ion was present. Which metal ions could be present?
7. Explain how they would use sodium hydroxide solution to distinguish between these two ions.
8. Explain why copper(II) solutions produce a pale blue precipitate then a dark blue solution when ammonia solution is added dropwise.

Worksheet A: Answers

1. *Complete the table below with either the name or the formulae of the substances.*

Name	*Formula*
Aluminium	**Al^{3+}**
Barium	**Ba^{2+}**
Calcium	*Ca^{2+}*
Chromium(III)	*Cr^{3+}*
Copper(II)	**Cu^{2+}**
Iron(II)	**Fe^{2+}**
Iron(III)	*Fe^{3+}*
Magnesium	**Mg^{2+}**
Manganese(II)	*Mn^{2+}*
Zinc(II)	*Zn^{2+}*
Sodium hydroxide	*NaOH*
Ammonia	**NH_3**

2. copper sulfate(VI) + sodium hydroxide → copper(II) hydroxide + sodium sulfate
3. $CuSO_4(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$
4. An alkaline solution has a higher concentration of hydroxide ions than hydrogen ions. Sodium hydroxide dissolves in solution, increasing the concentration of hydroxide ions. Ammonia dissolves in solution, reacting with water to produce ammonium ions and hydroxide ions, increasing the concentration of hydroxide ions in solution.

Worksheet D: Answers

Metal ion and colour	Colour of solution	Colour of precipitate in NaOH	Precipitate soluble in excess NaOH?	Colour of precipitate in NH_3	Precipitate soluble in excess NH_3?
Al^{3+}	Colourless	White	✓ (colourless solution)	White	✓ (colourless solution)
Ba^{2+}	Colourless	Faint white	✗	N/A	N/A
Ca^{2+}	Colourless	White	✗	N/A	N/A
Cr^{3+} / green or purple	Green or purple	Grey/green	✓ (dark green solution)	Grey-green	✗
Cu^{2+}	Pale blue	Pale blue	✗	Pale blue in dark blue solution	✓ (dark blue solution)
Fe^{2+}	Yellow/green	Green (turns brown)	✗	Green (turns brown)	✗
Fe^{3+}	Yellow/brown	Red-brown	✗	Red-brown	✗
Mg^{2+}	Colourless	White	✗	White	✗
Mn^{2+}	Faint pink	Off white → brown	✗	Off white → brown	✗
Zn^{2+}	colourless	white	✓	White	✓

1. Aluminium, barium, calcium, magnesium, zinc
2. The first four are non-transition metals, ie Group 1, 2, 3. Zinc is in the central block of the periodic table, but isn't classified as a transition element.
3. Chromium, copper, iron, manganese.
4. All four metals are transition metal elements.

Worksheet E: Answers

1. Aluminium, barium, calcium, magnesium, zinc.
2. Barium, calcium, magnesium
3. Magnesium
4. Barium, calcium.
5. Use a flame test: barium → green, calcium → orange/red.
6. Fe^{2+}, Cr^{3+}
7. Add a drop of the solution to a drop of sodium hydroxide and observe the green precipitate. Add excess sodium hydroxide – if a dark green solution is formed then Cr^{3+} is present. If the green precipitate remains and turned red/brown over a couple of minutes, Fe^{2+} was present.
8. Ammonia is basic, and reacts with water to produce hydroxide ions in solution. The copper(II) ions react with the hydroxide forming the pale blue copper(II) hydroxide solution. With excess ammonia, copper forms a dark-blue complex with ammonia.

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