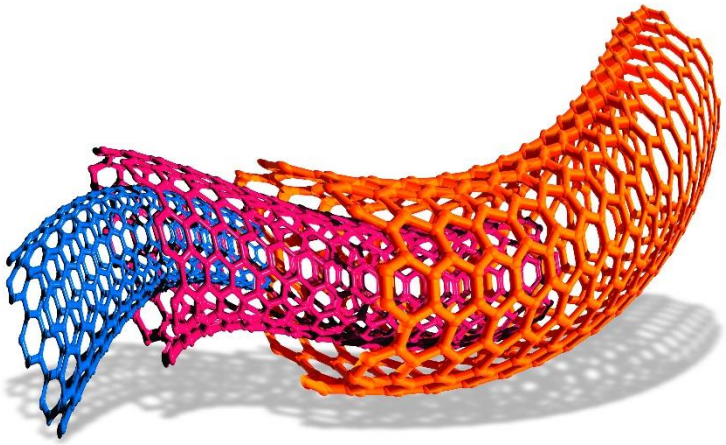
Cambridge Assessment International Education

Teaching Pack

The identification of unknown compounds **L** and **M**

Cambridge O Level

Chemistry 5070



Version 2.0

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Icons used in this pack:

Briefing lesson

Lab option 1: *Run the experiment*

Lab option 2: *Virtual experiment*

Debriefing lesson

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 *Teaching 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 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

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Lab lesson (1 hour*)	
Option 1: run the experiment	**Option 2: virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experiment skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experiment skills introduced in the *Briefing lesson*.

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Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases this also includes the opportunity to practise extended writing skills.

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

In this *Teaching Pack* you will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: The identification of unknown compounds **L** and **M**

This *Teaching Pack* focuses on qualitative analysis (the identification of ions and gases).

Qualitative analysis is commonly used to identify ionic substances by analysing their component anions and cations.

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

- 1.3 Identification of ions and gases

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- make and record observations
- interpret and evaluate experimental observations.

Prior knowledge

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

- 2.4 Ionic bonding
- 7.1 The characteristic properties of acids and bases
- 8.3 Transition elements

Going forward

The awareness and skill of making careful and accurate observations in this pack will assist learners in all areas of lab work. Learners could be encouraged to try to write balanced equations for some of the simpler chemical reactions that occur in this topic. Learners may be curious about any qualitative analysis tests for non-ionic compounds. Refer them to the bromine water test for unsaturation for alkenes. The chemical tests for water could also be discussed.

Briefing lesson: What is qualitative analysis?

Resources	• A range of white compounds (corn starch, sugar, baking powder, table salt) • Vinegar • Copper(II) sulfate pentahydrate (in a beaker) • Videos for qualitative analysis (cations, anions and flame tests) • Worksheets A and B
Learning objectives	By the end of the lesson: • ***all*** learners should be able to explain that specific chemical tests enable you to identify unknown substances and that there are specific tests for identifying anions and cations. • ***most*** learners should be able to highlight good lab technique and safety issues. • ***some*** learners should be able to explain that the basis of many of the tests used in qualitative analysis depends on the varying solubility of ionic substances.

Timings	Activity
15 min	**Starter/Introduction** Gather the learners around a demonstration bench to look at a number of white compounds (corn starch and sugar, baking powder and table salt). The demonstration details can be found in the *Teacher notes* section of the pack. The aim of this activity is to relate some everyday events and/or experiments, done in earlier years, to the idea of why we need to perform chemical tests to identify substances.
30 min	**Main lesson** The aim of this part of the lesson is to demonstrate the safety and good practice aspects of doing qualitative analysis. Hand out Worksheet A to each learner for reference and spend five minutes skimming through the main areas of the sheet – they will need to be familiar with this sheet when doing either of the lab lessons. Explain that each unknown substance they test will consist of anion tests and cation tests, which may include a flame test. In addition, alert them to the fact that they will be analysing gases produced in certain reactions. Give learners Worksheet B and show the unedited versions of the qualitative analysis videos. Play each of the videos in full. Pause at relevant points so that your learners can answer the questions on the sheet. Also remind learners of the safety aspects associated with the tests as you go.
15 min	**Plenary** Show the learners a sample of copper(II) sulfate pentahydrate in a small beaker (or show an image of these blue crystals). • Ask the learners to tell you which ion is the cation and which ion is the anion. • Ask the learners to write down the chemical formula. • Using their qualitative analysis sheets, ask the learners which tests could be performed to show the presence of the cation and the anion. Explain that in future sessions they will be given unknown samples and they will have to carry out the various tests to confirm what their unknown samples are.

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • *Teacher Walkthrough video* • Worksheets A, C and D • Equipment as outlined in the notes
Learning objectives	By the end of the lesson: • ***all*** learners should be able to perform the relevant tests on the unknown compounds. • ***most*** learners should be able to identify compounds **L** and **M**. • ***some*** learners will be able to evaluate and interpret their results.

Timings	Activity
10 min	**Starter/Introduction** Show the two unknown compounds, **L** and **M**. Tell the learners they will try to find out what they are using the qualitative analysis tests. **Safety** Ensure that all learners are wearing fastened lab coats. Make sure that they wear goggles throughout and that long hair is tied up safely. Remind learners about spillages. Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe. Ask the learners a few warm-up questions: What type of chemical bonding do compounds **L** and **M** have? Does the appearance of the compounds tell us anything about their identity?
30 min	**Main lesson** Learners should work in pairs. Learners should already have a copy of Worksheet A. Give each pair Worksheet C detailing the method for this experiment and Worksheet D to record their results. **Safety** Ideally, to minimise movement around the room, each pair of learners should have the chemical solutions placed in front of them. Additionally: 1. Each bench should have a small beaker labelled 'chemical waste' on it. The learners should use this for the disposal of solutions after each test. They should also be shown where the large bottle labelled 'chemical waste' is for the end of the lesson, into which they will empty the contents of their beakers. 2. Bunsen burners: indicate to the learners the position of the lit Bunsen burner and that they are burning with a yellow safety flame. Remind them that this must be changed to a blue flame when doing the test and then returned to a yellow safety flame afterwards. Compound **L** = $FeSO_4$ Compound **M** = KNO_3
5 min	Make sure that the learners tidy up after themselves, clean up any bench spills, empty the contents of their test-tubes and empty their 'chemical waste' into the main 'chemical waste' bottle. Finally, they should wash their hands.
15 min	**Plenary** Discuss each result with the students using the answers for Worksheet D.

Teacher notes

Watch the *Teacher walkthrough* video for unknown compounds **L** and **M** and read these notes.

Briefing lesson method

Corn starch and sugar:

1. Place a spatula full of each of the white powders into two separate small beakers. Tell the learners that one of them is corn starch and that the other is sugar. Ask the learners to tell you which is sugar and which is corn starch. How do they know this?
2. Remind the learners of the test for starch with iodine solution and the test for sugar with Benedict's solution. Ask the learners if they can remember the outcomes for the tests – if not, remind them using a video.

Baking powder and table salt:

1. Add a little vinegar to both substances and note the outcome.
2. Get the learners to identify the baking powder (it fizzes and bubbles).
3. Discuss with learners how they know that the other sample is table salt.
4. Lead them to the idea that a negative test does not mean that the sample is table salt and that a huge number of chemicals look just the same.
5. Make sure that you have a discussion about safety and that under no circumstances should students taste the powders.

For the main practical lesson, each pair will require:

- stoppered vials (or test-tubes) containing the following compounds:
  - iron(II) sulfate heptahydrate (1 g, fresh sample, labelled 'Compound **L**')
  - Potassium nitrate (1 g, labelled 'Compound **M**')
- a test-tube rack
- access to clean and dry test-tubes
- access to small, clean, dry spatulas
- distilled water (wash bottle)
- a loop of flame test wire attached to a suitable rod
- a Bunsen burner
- dilute hydrochloric acid [0.5 mol/dm^3]
- hydrochloric acid [5 mol/dm^3]
- fresh saturated limewater solution
- dilute nitric acid solution [0.5 mol/dm^3]
- silver nitrate solution
- barium nitrate solution
- a small piece of aluminium foil
- a strip of red litmus paper
- sodium hydroxide solution [1 mol/dm^3]
- aqueous ammonia solution [1 mol/dm^3]

Each bench should have a beaker labelled 'chemical waste' on it so that learners do not tip chemicals down the sink. Even though the quantities of waste should be minimal, it is good practice to encourage environmental awareness.

Additionally, a large bottle (in a central location) labelled 'chemical waste' should be made known to the learners so that at the end of the experiment, before they wash their hands and take their lab coats off, they tip the contents of their beakers into it.

Safety

The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.
It is your responsibility to carry out an appropriate risk assessment for this experiment.

Substance	Hazard	First aid
Iron(II) sulfate heptahydrate (solid)	 GHS07 *(moderate hazard* **MH**)	**In the eye:** flood the eye with gently-running tap water for at least 10 min. 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. **Dust breathed in:** remove the casualty to fresh air. See a doctor if breathing becomes difficult. **Spilt on the skin or clothing:** remove contaminated clothing and rinse it. Wash off the skin with plenty of water. **Spilt on the floor, bench, etc.:** scoop up compound (take care not to raise dust). Wipe up small solution spills or any traces of compound with cloth; for larger spills use a mineral absorbent (e.g. cat litter).
Potassium nitrate (solid)	 GHS03 *(oxidising* **O**)	**In the eye:** Flood the eye with gently-running tap water for 10 min. See a doctor if pain persists. **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:** brush compound off contaminated clothing. Rinse clothing or the skin as necessary **Spilt on the floor, bench, etc.:** brush up compound spills, trying to avoid raising dust, then wipe with a damp cloth.
Dilute hydrochloric acid [0.5 mol/dm^3]	 GHS07 (*moderate hazard* **MH**) (below a concentration of 2.7 mol/dm^3)	**In the eye:** flood the eye with gently-running tap water for 10 min. See a doctor. **Vapour breathed in:** remove to fresh air. Call a doctor if breathing becomes difficult. **Swallowed:** do no more than 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 contaminated clothing then drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** for release of gas, consider the need to evacuate the lab and open all windows. For large spills, and especially for (moderately) concentrated acid, cover with mineral absorbent (e.g. cat litter) and scoop into a bucket. Neutralise with sodium carbonate. Rinse with plenty of water. Wipe up small amounts with a damp cloth.

Substance	Hazard	First aid
Concentrated hydrochloric acid [2 mol/dm^3]	 GHS05 (*corrosive* **C**)  GHS07 (*moderate hazard* **MH**)	**In the eye:** flood the eye with gently-running tap water for 10 min. See a doctor. **Vapour breathed in:** Remove to fresh air. Call a doctor if breathing becomes difficult. **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 contaminated clothing then drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** for release of gas, consider the need to evacuate the lab and open all windows. For large spills, and especially for (moderately) concentrated acid, cover with mineral absorbent (e.g. cat litter) and scoop into a bucket. Neutralise with sodium carbonate. Rinse with plenty of water. Wipe up small amounts with a damp cloth and rinse it well.
Dilute nitric acid [0.5 mol/dm^3]	 GHS05 (*corrosive* **C**)	**In the eye:** flood the eye with gently-running tap water for 10 min. See a doctor. **Fumes breathed in:** remove the casualty to fresh air. Keep them warm. If more than a 'sniff' is inhaled, see a doctor even if no symptoms are apparent. **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:** quickly use a dry cloth or paper towel to wipe as much liquid off the skin as possible, then drench with plenty of water. If a large area is affected or blistering occurs, see a doctor. Remove contaminated clothing and rinse it well. **Spilt on the floor, bench, etc.:** wipe up small amounts with a damp cloth and rinse it well. For larger amounts, and especially for (moderately) concentrated acid, cover with mineral absorbent (e.g. cat litter) and scoop into a bucket. Neutralise with sodium carbonate. Rinse with plenty of water.
Silver nitrate solution	 GHS09 (*hazardous to the aquatic environment* **N**)	**In the eye:** flood the eye with gently-running tap water for at least 10 min. See a doctor. **Swallowed:** do no more than 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 contaminated clothing and rinse it. Wash off the skin with plenty of water. If the silver nitrate produces more than small burns, see a doctor. **Spilt on the floor, bench, etc.:** wear eye protection and gloves. Scoop up the solid. Rinse the area with water and wipe up, rinsing repeatedly.
Barium nitrate solution	LOW HAZARD	**In the eye:** flood the eye with gently-running tap water for at least 10 min. See a doctor.

Substance	Hazard	First aid
		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:** brush off any compound. Remove contaminated clothing. Drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. Rinse contaminated clothing with water. **Spilt on the floor, bench, etc.:** scoop up any compound. Rinse the area with water, diluting greatly. Solutions should be treated with mineral absorbent (e.g. cat litter).
Ammonia solution [1 mol/dm^3]	 GHS05 (*corrosive* **C**)  GHS07 (*moderate hazard* **MH**)  GHS09 (*hazardous to the aquatic environment* **N**)	**In the eye:** flood the eye with gently-running tap water for at least 20 min (for alkalis). See a doctor. If it is necessary to go to hospital, continue washing the eye during the journey in an ambulance. **Vapour breathed in:** remove the casualty to fresh air. Call a doctor if breathing becomes difficult. **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 contaminated clothing. Drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** consider the need to evacuate the lab and open windows if large amounts are spilt and especially for (moderately) concentrated solutions. Cover with mineral absorbent (e.g. cat litter) and scoop into a bucket. Neutralise with citric acid. Rinse with plenty of water. Wipe up small amounts with a damp cloth and rinse it well.
Sodium hydroxide solution [1 mol/dm^3]	 GHS05 (*corrosive* **C**)	**In the eye:** flood the eye with gently-running tap water for at least 20 min. See a doctor. If a visit to hospital is necessary, continue washing the eye during the journey in an ambulance. **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 contaminated clothing. Drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** wipe up small amounts with a damp cloth and rinse it well. For larger amounts, and especially for (moderately) concentrated solutions, cover with mineral absorbent (e.g. cat litter) and scoop into a bucket. Neutralise with citric acid. Rinse with plenty of water.

Teacher method

This is your version of the method for this experiment.

Do not share this method with learners. Give them Worksheet C and Worksheet D.

Before you begin
Plan how you will group your learners during the lab session.

Think about:
- the number of pairs of learners you will need to cater for
- the amount of equipment/chemicals required
- where the chemicals will be placed in the lab
- the waste protocol for the lab
- the appropriate risk assessments and ensure they have been carried out.

Experiment
Circulate during the practical in case learners encounter any difficulties.

Steps	**Notes**
1. Check that learners have all the chemicals they need in front of them.	*If this is not possible because of space in the lab, set the chemicals out safely for easy access.*
2. Check that the learners have **Worksheets A**, **C** and **D**.	
3. Show the unknown samples labelled as '**L**' and '**M**' in vials or test-tubes.	*Here is where you can ask:* *1. What type of chemical bonding do compounds **L** and **M** have?* *2. Does the appearance of the compounds tell us anything about their identity?*
4. Before they start, warn the learners about safety and good practice for this experiment.	*Always monitor learners doing the flame tests. Check that they use the blue flame for the test and return the Bunsen burner back to the safety flame afterwards.* *Also caution the students to pay particular attention when performing the nitrate test, ensuring that they only heat the mixture gently and direct the contents of the tube away from themselves and other learners.*

5. Get the learners to perform each test and write their answers on Worksheet D.

Check to make sure that every learner is recording each observation as soon as they have completed each test.

Also ensure that both learners in the pair are taking an active role in the experiment.

Clean-up

After the practical learners should:

- empty their chemical waste into the main chemical waste bottle in a central location
- tidy up their work space and put things away as instructed
- ensure any spillages have been mopped up
- wash their hands with soap and water.

Details of the tests

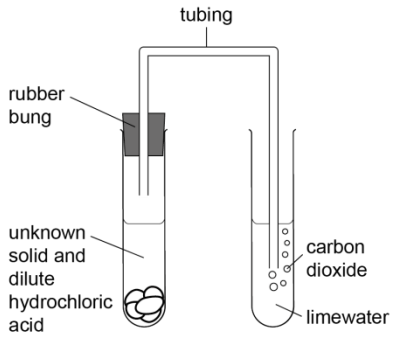
Here are the details of how to carry out each of the tests for the anions, cations and flame tests used in qualitative analysis. Before allowing your learners to do these tests, familiarise yourself with them.

Anions

1. <u>Test for carbonate ions in solution:</u>
   (a) Add dilute hydrochloric acid (1 cm^3).
   (b) If effervescence/fizzing/bubbles are observed, the gas should be tested with limewater solution to confirm that it is carbon dioxide.
   (c) To test with limewater, you will require two test-tubes, a stopper and some tubing.
   (d) Set-up the apparatus as shown below:

Safety

Ensure learners use a light twisting action to place the bung in the mouth of the test-tube so that the gas cannot escape. Tell them to not press too hard as the glass tubing is easily broken.



   (e) The limewater will go cloudy as the CO_2 is bubbled through it.

2. Test for chloride/bromide/iodide ions in solution:
   (a) Acidify a solution containing the chloride/bromide/iodide ions (1 cm^3) by adding dilute nitric acid (5 drops).
   (b) Add aqueous silver nitrate solution (10 drops) and shake gently.
      (i) If chloride ions are present, a white precipitate will form.
      (ii) If bromide ions are present, a cream precipitate will form.
      (iii) If iodide ions are present, a yellow precipitate will form.
      Note: this is a very sensitive test and deionised water should be used.

3. Test for nitrate ions in solution:

Safety
Do this test in the fume cupboard.

   (a) Add dilute sodium hydroxide solution (10 drops) to a solution containing nitrate ions (1 cm^3) and gently shake the mixture.
   (b) Add a small piece of aluminium foil to the tube.
   (c) Heat the tube gently for a few seconds only, ensuring that the mouth of the test-tube is facing away from yourself (and the learners). Then remove from the source of heat. Nothing much may appear to happen initially, but once the reaction starts it is very exothermic and can occasionally cause the contents of the tube to erupt out.
   (d) After gentle heating, the aluminium will be seen to be reacting vigorously and there is therefore no need for further heating.
   (e) At this point you should cautiously test for the presence of ammonia gas by placing a piece of damp red litmus paper close to the mouth of the test-tube.
   A common cause of error is the learner touching the litmus paper against the inside of the test-tube making contact with the sodium hydroxide. This should be avoided, since it gives a false result.

4. Test for sulfate ions in solution:
   (a) Acidify a solution containing the sulfate ions (1 cm^3) by adding dilute nitric acid (5 drops).
   (b) Add aqueous barium nitrate solution (10 drops) and shake gently.
   (c) If sulfate ions are present, a white precipitate will form.

5. Test for sulfite ions in solution:

   This test must be conducted carefully in a fume cupboard. If no fume cupboard is available, then use the video to show this test.

Safety
Sulfur dioxide is a pungent, toxic gas, and is particularly harmful to people with respiratory problems. Therefore, learners with such conditions should take extra care and not stand right next to the fume cupboard or smell the contents of the test-tube themselves.

   (a) Add a small volume of hydrochloric acid to the test sample and shake gently.
   (b) Warm gently and remove from the source of heat.

(c) Immediately test for the presence of sulfur dioxide gas using potassium manganate(VII) solution.
(d) Place a drop of acidified potassium manganate(VII) solution onto a strip of filter paper.
(e) If sulfur dioxide gas is present, the purple-stained filter paper will become colourless.

Cations

1. Adding aqueous sodium hydroxide:
   (a) Make a solution of the unknown and put 1 cm^3 (max.) into a test-tube.
   (b) Add 1 cm^3 (max.) sodium hydroxide solution and shake carefully.
   (c) Record the appearance of any precipitate formed.
   (d) Continue to add sodium hydroxide solution and shake – is the precipitate soluble or insoluble in excess?

2. Adding aqueous ammonia:
   (a) Make a solution of the unknown and put 1 cm^3 (max.) into a test-tube.
   (b) Add 1 cm^3 (max.) ammonia solution and shake carefully.
   (c) Record the appearance of any precipitate formed.
   (d) Continue to add ammonia solution and shake – is the precipitate soluble or insoluble in excess?

3. Test for ammonium ions in solution:
   (a) Add sodium hydroxide solution (1 cm^3).
   (b) Warm the mixture gently in a Bunsen flame and then remove from the heat.
   (c) Moisten a piece of red litmus paper and hold it near the mouth of the test-tube. If the paper turns blue, this indicates that ammonia gas is present which confirms the presence of ammonium ions.
   A common cause of error is the learner touching the litmus paper against the inside of the test-tube making contact with the sodium hydroxide. This should be avoided, since it gives a false result.

4. Flame tests*
   (a) Dip the flame test wire into a test-tube containing a small amount of hydrochloric acid [2 mol/dm^3].
   (b) Heat the wire for a few seconds in the blue flame of the Bunsen burner.
   (c) Dip the wire into a solution of the test substance.
   (d) Observe and record the flame colour.
   (e) If multiple-flame tests are being performed make sure that the wire is cleaned by dipping it into the hydrochloric acid and heating in the blue flame, repeating this process until there is no positive flame test colour.

*Learners do not need to know the flame colour for calcium.

Lab lesson: Option 2 – virtual experiment

Resources	• *Virtual Experiment video* for unknown **L** and **M** • Worksheets A, C and D
Learning objectives	By the end of the lesson: • ***all*** learners should be able to make relevant observations based on the tests on the unknown compounds. • ***most*** learners should be able to identify compounds **L** and **M**. • ***some*** learners will be able to evaluate and interpret their results.

Timings	Activity
10 min	**Starter/Introduction** Gather the learners around the screen and ensure they have the relevant sheets (Worksheet A, Worksheet C and Worksheet D). Introduce the virtual practical. Tell the learners they will try to find out the cations and anions present in two compounds, **L** and **M**. Show them the start of the *Virtual Experiment video* for the two unknown compounds. What do they observe from just looking at them? The first thing the students need to do on Worksheet D is to describe the appearance of compounds **L** and **M**. (Point them in the direction that it is the colour, not the texture that is important.)
20 min	**Main lesson** **Tests on compound L** Focus on the tests and the observations at this stage. Allow the learners to work out what each observation or observations indicate. As per Worksheet D the learners will: (a) discuss the significance of the crystals being green coloured. (b) and (c) show the addition of a small amount sodium hydroxide to a solution of **L** and then a large excess. Repeat the procedure with aqueous ammonia. Encourage learners to write down their observations carefully. (d) Next, show the addition of acidified silver nitrate solution. Even though the test is negative for chloride ions, students should be discouraged from writing 'nothing'. (e) To the final portion of the aqueous salt **L**, acidified barium nitrate was added. The learners will observe a white precipitate forming indicating the presence of the sulfate ion. They may comment on the fact that the aqueous phase is still green, but be prepared to tell them that the formation and colour of the precipitate is the important observation. The learners should now be able to decide what compound **L** is. Compound **L** is $FeSO_4$. Weaker students may need help with writing down the chemical formula. *Continues on next page …*

Timings	Activity
20 min	**Tests on compound M** Again, focus on the execution of the tests and the observations. As per Worksheet D the learners will: (a) Discuss the significance of the crystals being white. (b) Show the negative test for a chloride. (c) The nitrate test is positive. Point out the safety issues and also that the instructor is careful not to touch the damp red litmus paper on the side of the test-tube. (d) Show the addition of a small amount sodium hydroxide to a solution of **M** and then a large excess. Repeat the procedure with aqueous ammonia. Encourage learners to write 'no precipitate formed' rather than 'nothing' or leaving the space blank altogether. (e) Show the video of the flame test producing a positive test for the potassium ion. Finally, for compound **M**, the learners should now be able to decide what the compound is. Compound **M** is KNO_3. Weaker learners may need help with writing down the chemical formula.
10 min	**Plenary** Discuss each result with the learners using the suggested answers for Worksheet D.

Debriefing lesson: Compound naming and writing chemical formulae

Resources	• Worksheets **E** and **F**
Learning objectives	By the end of the lesson: • ***all*** learners should be able to construct simple chemical formulae formed between simple anions and cations and name them. • ***most*** learners should be able to do the above, plus use some of the polyatomic ions (compound ions), correctly in their formulae and name them correctly. • ***some*** learners will be able to confidently construct chemical formulae using a range of polyatomic ions, including the ammonium ion. They will also be able to deconstruct chemical formulae correctly, naming the constituent ions with the correct charges.

Timings	Activity
10 min	**Starter/Introduction** Write down the formulae of the compounds used in the practical lesson for compounds **L** ($FeSO_4$) and **M** (KNO_3). **Note:** If you haven't followed this pack specifically but are using this lesson, then use the chemical formulae of the unknowns you have tested or the chemical formulae of your choice. Ask the learners to identify the names and charges on the ions. For compound **L**, learners may need help with naming iron as 'iron(II)' and what the '(II)' signifies. Now that there is a list of ions on the board, ask how they could be combined together in different combinations to produce different compounds. If there are no suggestions, lead the learners towards: K_2SO_4 and $Fe(NO_3)_2$, for example. Ask learners how these compounds might be named. Explain to them that these are real chemicals that actually exist. If you have access to these chemicals then show them to the learners.
20 min	**Main lesson** Give out Worksheet E. Learners should work through this. Provide support where needed.
15 min	Go over the answers with the learners using the suggested answers provided.
15 min	**Plenary** Play the 'Guess the compound' game using Worksheet F.

Worksheets and answers

	Worksheets	Answers
For use in the *Briefing lesson*:		
A: Notes for use in qualitative analysis	**23**	**—**
B: Performing qualitative analysis tests	**25**	**35**
For use in *Lab lesson: Option 1*:		
A: Notes for use in qualitative analysis	**23**	**—**
C: Method	**27**	**—**
D: Results	**29**	**37**
For use in *Lab lesson: Option 2*:		
A: Notes for use in qualitative analysis	**23**	**—**
C: Method	**27**	**—**
D: Results	**29**	**37**
For use in the *Debriefing lesson*:		
E: Naming and chemical formulae	**31**	**39**
F: Guess the compound	**33**	**41**

Worksheet A: Notes for use in qualitative analysis

Tests for anions

Anion	Test	Test result
carbonate (CO_3^{2-})	add dilute acid	effervescence, carbon dioxide produced
chloride (Cl^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
bromide (Br^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	cream ppt.
iodide (I^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	yellow ppt.
nitrate (NO_3^-) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulfate (SO_4^{2-}) [in solution]	acidify, then add aqueous barium nitrate	white ppt.
sulfite (SO_3^{2-})	add dilute hydrochloric acid, warm gently and test for the presence of sulfur dioxide	sulfur dioxide produced will turn acidified aqueous potassium manganate(VII) from purple to colourless

Tests for aqueous cations

Cation	Effect of aqueous sodium hydroxide	Effect of aqueous ammonia
aluminium (Al^{3+})	white ppt., soluble in excess giving a colourless solution	white ppt., insoluble in excess
ammonium (NH_4^+)	ammonia produced on warming	—
calcium (Ca^{2+})	white ppt., insoluble in excess	no ppt., or very slight white ppt.
chromium(III) (Cr^{3+})	green ppt., soluble in excess	grey-green ppt., insoluble in excess
copper (Cu^{2+})	light blue ppt., insoluble in excess	light blue ppt., soluble in excess, giving a dark blue solution
iron(II) (Fe^{2+})	green ppt., insoluble in excess	green ppt., insoluble in excess
iron(III) (Fe^{3+})	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess

zinc (Zn^{2+})	white ppt., soluble in excess, giving a colourless solution	white ppt., soluble in excess, giving a colourless solution

Worksheet A: Notes for use in qualitative analysis

Tests for gases

gas	test and result
ammonia (NH_3)	turns damp, red litmus paper blue
carbon dioxide (CO_2)	turns limewater milky
chlorine (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	'pops' with a lighted splint
oxygen (O_2)	relights a glowing splint
sulfur dioxide (SO_2)	turns acidified aqueous potassium manganate(VII) from purple to colourless

Flame test for metal ions

metal ion	flame colour
lithium (Li^+)	red
sodium (Na^+)	yellow
potassium (K^+)	lilac
copper(II) (Cu^{2+})	blue-green

Solubility rules

These are a guide to help you appreciate qualitative analysis more fully.

Ion [solubility in water]	Exceptions
All nitrates (NO_3^-) are soluble	None
All halides (Cl^-, Br^- and I^-) are soluble	Silver (Ag^+) and lead (Pb^{2+})
All sulfates (SO_4^{2-}) are soluble	Lead (Pb^{2+}), barium (Ba^{2+}) and calcium (Ca^{2+})
All carbonates (CO_3^{2-}) are insoluble	Sodium (Na^+), potassium (K^+) and ammonium (NH_4^+)

Worksheet B: Performing qualitative analysis tests

Answer these questions which are based on the qualitative analysis tests you have just seen in the video(s).

Test for carbonate anion

(a) What do you observe when dilute hydrochloric acid is added to a carbonate?

……..

(b) Which reagent is used for testing the gas produced and what is the result?

……..

……..

(c) Explain why it is very important to keep the stopper kept on a freshly made up bottle of limewater.

……..

……..

Test for halide anion (chloride, bromide and iodide)

(a) What is the name of the reagent used to test for the presence of halide ions?

……..

(b) Define the term precipitate.

……..

……..

(c) Why is it very important to use distilled water in the test for chloride ions?

……..

……..

Test for sulfite anion

(a) Which gas is produced during a positive test for a sulfite?

……..

(b) What safety precautions need to be taken when performing this test?

……..

……..

Worksheet B: Performing qualitative analysis tests

Test for chromium(III) cation

(a) What does ‘in excess’ mean?

……..

……..

(b) What are the main differences in the results obtained when using aqueous sodium hydroxide, compared with using aqueous ammonia?

……..

……..

……..

Test for aluminium cation

(a) What is the result obtained, when a small amount of aqueous sodium hydroxide is added to aqueous aluminium ions?

……..

……..

(b) What happens when you add an excess of this reagent?

……..

……..

(c) How is the result of this test different to that obtained with aqueous ammonia?

……..

……..

Flame tests

(a) What do you need in order to perform a typical flame test?

……..

……..

(b) What safety precautions should be taken?

……..

……..

……..

Worksheet C: Method

This sheet is to support you in understanding the tests used to identify your unknown substances

Anions

1. Test for carbonate

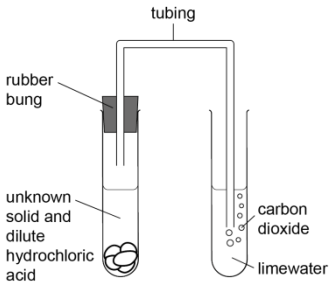
(a) Add dilute hydrochloric acid (1 cm^3) to your unknown compound.

(b) If effervescence/fizzing/bubbles are observed, the gas should be tested with a limewater solution. This will confirm the presence of carbon dioxide.

(c) To test with limewater, you will require two test-tubes, a rubber bung and some tubing.

(d) The set-up of the apparatus is shown opposite:

(e) The limewater will go cloudy as the carbon dioxide is bubbled through it.



Safety

Use a light twisting action to place the bung in the mouth of the test tube so that the gas cannot escape. Be careful not to press too hard, or you might break the glass tubing into your hand. Ask your teacher for help if you are unsure.

2. Test for chloride/bromide/iodide

(a) Acidify a solution of your unknown (1 cm^3) by adding dilute nitric acid (5 drops).

(b) Add aqueous silver nitrate solution (10 drops) and shake gently.

(i) If chloride ions are present, a white precipitate will form.

(ii) If bromide ions are present, a cream precipitate will form.

(iii) If iodide ions are present, a yellow precipitate will form.

Note: this is a very sensitive test and deionised water should be used.

3. Test for nitrate **(do this test in a fume cupboard)**

(a) Add dilute sodium hydroxide solution (10 drops) to a solution of your unknown (1 cm^3) and gently shake the mixture.

(b) Add a small piece of aluminium foil to the tube.

(c) Heat the tube gently for a few seconds only, ensuring that the mouth of the test-tube is facing away from yourself. Then remove from the source of heat.

(d) After gentle heating, the aluminium will be seen to be reacting vigorously and there is therefore no need for further heating.

(e) At this point you should cautiously test for the presence of ammonia gas by placing a piece of damp red litmus paper close to the mouth of the test-tube.
Make sure you don't touch the inside of the test-tube with the litmus paper!

4. Test for sulfate

(a) Acidify a solution containing your unknown (1 cm^3) by adding dilute nitric acid (5 drops).

(b) Add aqueous barium nitrate solution (10 drops) and shake gently.

(c) If sulfate ions are present, a white precipitate will form.

Worksheet C: Method

5. Test for sulfite **(do this test in a fume cupboard)**

(a) Add a small volume of hydrochloric acid to your unknown in a test-tube and shake gently.

(b) Warm gently and remove from the source of heat.

(c) Immediately test for the presence of sulfur dioxide gas.

(d) Place a drop of acidified potassium(VII) manganate solution onto a strip of filter paper and place in the neck of the test-tube.

(e) If sulfur dioxide gas is present, the purple-stained filter paper will become colourless.

Cations

1. Adding aqueous sodium hydroxide:

(a) Make a solution of the unknown and put 1 cm^3 (max.) into a test-tube.

(b) Add 1 cm^3 (max.) sodium hydroxide solution and shake carefully.

(c) Record the appearance of any precipitate formed.

(d) Continue to add sodium hydroxide solution and shake – is the precipitate soluble or insoluble in excess?

2. Adding aqueous ammonia:

(a) Make a solution of the unknown and put 1 cm^3 (max.) into a test-tube.

(b) Add 1 cm^3 (max.) ammonia solution and shake carefully.

(c) Record the appearance of any precipitate formed.

(d) Continue to add ammonia solution and shake – is the precipitate soluble or insoluble in excess?

3. Test for ammonium

(a) Make a solution of the unknown and put 1 cm^3 (max.) into a test-tube.

(b) Add sodium hydroxide solution (1 cm^3) to the unknown solution.

(c) Warm the mixture gently in a Bunsen flame and then remove from the heat.

(d) Moisten a piece of red litmus paper and hold it near the mouth of the test-tube. If the paper turns blue, this indicates that ammonia gas is present, which confirms the presence of ammonium ions. Make sure you don't touch the inside of the test-tube with the litmus paper!

Flame tests

(a) Dip the flame test wire into a test-tube containing a small amount of hydrochloric acid [2 mol/dm^3].

(b) Heat the wire for a few seconds in the blue flame of the Bunsen burner.

(c) Dip the wire into a solution of the unknown.

(d) Place the wire in the centre of the flame.

(e) Observe and record the flame colour.

Worksheet D: Results

You have been provided with two compounds, labelled **L** and **M**.

Carry out the following tests on the compounds, entering your results and conclusions in the table.

Tests on sample L	
tests	**observations**
(a) Describe the appearance of the compound.	…….
(b) Dissolve compound **L** (one small spatula full) in distilled water (4 cm^3) with stirring until a solution is formed. (Do not worry if a very small amount of undissolved solid remains). Divide this solution equally into four portions in four separate test-tubes.	
(c) To the first portion, add aqueous sodium hydroxide (10 drops). Now add an excess of aqueous sodium hydroxide noting any changes.	…… …….
(d) To the second portion, add aqueous ammonia solution (10 drops) Now add an excess of aqueous sodium hydroxide noting any changes.	…… …….
(e) To the third portion, acidify with dilute nitric acid (2 drops) and add a solution of silver nitrate (5 drops).	…….
(f) To the final portion, acidify with dilute nitric acid (2 drops) add a solution of barium nitrate (5 drops).	…….

- Write down the name and formula of the cation and anion that you have identified above:
    - cation: …… anion: ……..
- Name of compound **L**: …….
- Chemical formula of compound **L**: ……..

Worksheet D: Results

Tests on sample M	
tests	**observations**
(a) Describe the appearance of the compound	…….
(b) Dissolve solid **M** (one small spatula full) in distilled water (5 cm^3) with stirring until a solution is formed. (Do not worry if a very small amount of undissolved solid remains). Divide this solution equally into five portions in five separate test-tubes.	
(c) To the first portion, add aqueous sodium hydroxide (10 drops) Now add an excess of aqueous sodium hydroxide noting any changes.	…… …….
(d) To the second portion, add aqueous ammonia solution (10 drops) Now add an excess of aqueous sodium hydroxide noting any changes	…… …….
(e) To the third portion of the solution, perform a flame test. Record the colour the flame.	…….
(f) To the fourth portion, acidify with dilute nitric acid (2 drops) and add a solution of silver nitrate (5 drops).	…….
(g) To the second portion, add aqueous sodium hydroxide (10 drops) followed by a small piece of aluminium foil. Warm the mixture **gently**. Next, hold a piece of damp, red litmus paper close to the mouth of the test-tube and record any colour change.	…….

- Write down the name and formula of the cation and anion that you have identified above:
    - cation: ……. anion: ……..
- Name of compound **M**: …….
- Chemical formula of compound **M**: …….

Worksheet E: Naming and chemical formulae

Here you will practice writing chemical formulae and naming compounds.

1. Complete the sentences using the keywords below. These may be used more than once.

gain	positively	neutral
group	negatively	electrons
donate	ions	protons

Atoms of all of the elements in the Periodic Table are ……. in charge.

The reason for this is because all atoms contain an equal number of ……. and ……..

Depending on their ……. in the Periodic Table, metal atoms can ……. between one and three electrons to form ……. charged ……..

Atoms of non-metals ……. electron(s) from metal atoms, to form ……. charged ……..

2. (a) Lithium is in Group 1 of the Periodic Table. It loses one electron to form a lithium ion (Li^+). Bromine is a non-metal in group 7 forming bromide ions (Br^-).

What is the name and formula of the compound formed between these two elements?

Name: ……....

Formula: ……....

(b) Magnesium, in Group 2, forms Mg^{2+} ions.

What is the name and formula of the compound formed between magnesium and bromine?

Name: ……....

Formula: ……....

Worksheet E: Naming and chemical formulae

3. With reference to the Periodic Table, write the formula of the ions, and the names and formulae of the resulting compounds in the table below. The first row has been completed for you.

Elements involved in bonding	Cation formed	Anion formed	Formulae of the resulting ionic compound	Name of the resulting ionic compound
Sodium and iodine	Na^+	I^-	NaI	Sodium iodide
Potassium and oxygen				
Strontium and chlorine				
Aluminium and oxygen				
Magnesium and nitrogen				

4. Many of the ionic compounds used in qualitative analysis, contain polyatomic ions (compound ions). List the names and formulae of the ones you need to be familiar with from **Worksheet A**.

Name of the ion	Formula of the ion
sulfate	
carbonate	
nitrate	
ammonium	
sulfite	
hydroxide	

Challenge: There is a common reagent used in the chemistry lab, which has the formula $(NH_4)_2Fe(SO_4)_2$.

Try to work out the numbers of each ion in the compound, their names and their charges.

……

……

……

……

Worksheet F: Guess the compound

Read each passage and try to guess what the compound is. Write both the name and formulae in the spaces provided.

1. I am a blue crystalline solid. My cation has a charge of 2+. In its neutral form it is a shiny red-brown coloured metal used in coins and wiring. My polyatomic anions, which are composed of sulfur and oxygen atoms in a ratio of 1 : 4, have a charge of 2–.

…… ……...

2. I confuse many people because I have polyatomic ions with a positive charge. When I react with acids I produce lots of gas that turns limewater milky.

…… ……...

3. I am dangerous. When I react with acids I break down to produce a pungent, toxic gas. When placed in a hot flame I produce a red flame.

…… ……...

4. I react with acidified silver nitrate to produce a white precipitate. My cations are really positive and both of the precipitates they form with alkalis are insoluble in excess.

…… ……...

5. My anion is derived from the halogens and I form the darkest of the three precipitates with a valuable nitrate. My cation doesn't produce precipitates, but my flame colour is also the name of a flower.

…… ……...

6. Both of my ions form white precipitates. My cation produces precipitates that have different solubilities in excess of different alkalis. My anion forms its white precipitate with a Group II nitrate.

…… ……...

Worksheet B: Answers

Test for carbonate anion

(a) What do you observe when dilute hydrochloric acid is added to a carbonate?

effervescence / bubbling / fizzing

(b) Which reagent is used for testing the gas produced and what is the result?

Limewater solution; the solution will turn cloudy/milky in the presence of carbon dioxide

(c) Explain why it is very important to keep the stopper kept on a freshly made up bottle of limewater.

So the carbon dioxide in the air does not turn the limewater solution cloudy/milky

Test for halide anion (chloride, bromide and iodide)

(a) What is the name of the reagent used to test for the presence of halide ions?

Silver nitrate solution

(b) Explain the term precipitate.

A precipitate is formed when two solutions react together producing a solid substance that may or may not be dissolved in excess.

(c) Why is it very important to use distilled water in the test for chloride ions?

The test for chloride is a very sensitive test and as tap water contains chloride ions, these will cause a precipitate to form and give a false result.

Test for sulfite anion

(a) Which gas is produced during a positive test for a sulfite?

sulfur dioxide (SO_2) gas

(b) What safety precautions need to be taken when performing this test?

The test must be done in a fume cupboard as sulfur dioxide is a toxic gas.

Worksheet B: Answers

Test for chromium(III) cation

(a) What does 'in excess' mean?

In excess means adding much more of one reagent than is needed for complete reaction

(b) What are the main differences in the results obtained when using aqueous sodium hydroxide, compared with using aqueous ammonia?

One difference is in the solubility of the precipitate. With ammonia solution, the precipitate is insoluble in excess. Additionally, the colour of the precipitate is a grey-green colour compared to the green colour obtained with sodium hydroxide solution.

Test for aluminium cation

(a) What is the result obtained when a small amount of aqueous sodium hydroxide is added to aqueous aluminium ions?

A white precipitate is formed

(b) What happens when you add an excess of this reagent?

The precipitate dissolves to produce a colourless solution

(c) How is the result of this test different to that obtained with aqueous ammonia?

The precipitate formed is insoluble in excess reagent

Flame tests

(a) What do you need in order to perform a typical flame test?

The most important piece of equipment is a flame test wire made from an inert material that does not produce a flame colour itself. You also need concentrated hydrochloric acid to clean the wire in between tests and a Bunsen burner.

(b) What safety precautions should be taken?

Between the tests, and after use, the Bunsen burner should be left on a yellow safety flame. Long hair should be tied up and a lab coat and safety goggles must be worn. Care should be taken when using concentrated hydrochloric acid so that it does not splash.

Worksheet D: Answers

Tests on sample L	
tests	**observations**
(a) Describe the appearance of the compound.	*light green crystals*
(b) Dissolve compound **L** (one small spatula full) in distilled water (4 cm^3) with stirring until a solution is formed. (Do not worry if a very small amount of undissolved solid remains). Divide this solution equally into four portions in four separate test-tubes.	
(c) To the first portion, add aqueous sodium hydroxide (10 drops). Now add an excess of aqueous sodium hydroxide noting any changes.	*a green precipitate formed* *the precipitate is insoluble in excess*
(d) To the second portion, add aqueous ammonia solution (10 drops) Now add an excess of aqueous sodium hydroxide noting any changes.	*a green precipitate formed* *the precipitate is insoluble in excess*
(e) To the third portion, acidify with dilute nitric acid (2 drops) and add a solution of silver nitrate (5 drops).	*no precipitate formed/no change observed*
(f) To the final portion, acidify with dilute nitric acid (2 drops) add a solution of barium nitrate (5 drops).	*a white precipitate formed*

- Write down the name and formula of the cation and anion that you have identified above:
  - cation: *iron(II)* Fe^{2+} anion: *sulfate* SO_4^{2-}
- Name of compound **L**: *iron(II) sulfate*
- Chemical formula of compound **L**: $FeSO_4$

Worksheet D: Answers

Tests on sample M	
tests	**observations**
(a) Describe the appearance of the compound	*white crystals*
(b) Dissolve solid **M** (one small spatula full) in distilled water (5 cm^3) with stirring until a solution is formed. (Do not worry if a very small amount of undissolved solid remains). Divide this solution equally into five portions in five separate test-tubes.	
(c) To the first portion, add aqueous sodium hydroxide (10 drops) Now add an excess of aqueous sodium hydroxide noting any changes.	*no precipitate was observed* *no changes on addition of excess sodium hydroxide*
(d) To the second portion, add aqueous ammonia solution (10 drops) Now add an excess of aqueous sodium hydroxide noting any changes.	*no precipitate was observed* *no changes on addition of excess ammonia*
(e) To the third portion of the solution, perform a flame test. Record the colour the flame.	*a lilac coloured flame was observed*
(f) To the fourth portion, acidify with dilute nitric acid (2 drops) and add a solution of silver nitrate (5 drops).	*no precipitate formed/no change observed*
(g) To the fifth portion, add aqueous sodium hydroxide (10 drops) followed by a small piece of aluminium foil. Warm the mixture **gently**. Next, hold a piece of damp, red litmus paper close to the mouth of the test-tube and record any colour change.	*upon warming the mixture, a vigorous reaction was observed with lots of bubbling* *the red litmus paper turned blue*

- Write down the name and formula of the cation and anion that you have identified above:
  - cation: *potassium* K^+ anion: *nitrate* NO_3^-
- Name of compound **M**: *potassium nitrate*
- Chemical formula of compound **M**: KNO_3

Worksheet E: Answers

1.

Atoms of all of the elements in the Periodic Table are *neutral* in charge.

The reason for this is because all atoms contain an equal number of *protons* and *electrons*.

Depending on their *group* in the Periodic Table, metal atoms can *donate* between one and three electrons to form *positively* charged *ions*.

Atoms of non-metals *gain* electron(s) from metal atoms, to form *negatively* charged *ions*.

2. (a)

Name: *lithium bromide*

Formula: *LiBr*

(b)

Name: *magnesium bromide*

Formula: $MgBr_2$

Worksheet E: Answers

3.

Elements involved in bonding	Cation formed	Anion formed	Formulae of the resulting ionic compound	Name of the resulting ionic compound
Sodium and iodine	Na^+	I^-	NaI	Sodium iodide
Potassium and oxygen	K^+	O^{2-}	K_2O	Potassium oxide
Strontium and chlorine	Sr^{2+}	Cl^-	$SrCl_2$	Strontium chloride
Aluminium and oxygen	Al^{3+}	O^{2-}	Al_2O_3	Aluminium oxide
Magnesium and nitrogen	Mg^{2+}	N^{3-}	Mg_3N_2	Magnesium nitride

4.

Name of the ion	Formula of the ion
sulfate	SO_4^{2-}
carbonate	CO_3^{2-}
nitrate	NO_3^-
ammonium	NH_4^+
sulfite	SO_3^{2-}
hydroxide	OH^-

Challenge

Two NH_4^+ (ammonium) ions, two SO_4^{2-} (sulfate) ions and one Fe^{2+} (iron(II)) ion

Worksheet F: Answers

1. Copper(II) sulfate $CuSO_4$
2. Ammonium carbonate $(NH_4)_2CO_3$
3. Lithium sulfite Li_2SO_3
4. Iron(III) chloride $FeCl_3$
5. Potassium iodide KI
6. Aluminium sulfate $Al_2(SO_4)_3$

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