GCSE · AQA · Chemistry

2 hours 18 questions

Exam Questions

Methods of Identifying Ions

Flame Tests / Metal Hydroxides / Carbonates / Halides / Sulfates / Required Practical: Identifying Ions / Instrumental Methods / Flame Emission Spectroscopy

Easy (6 questions)	/35
Medium (7 questions)	/39
Hard (5 questions)	/47
Total Marks	**/121**

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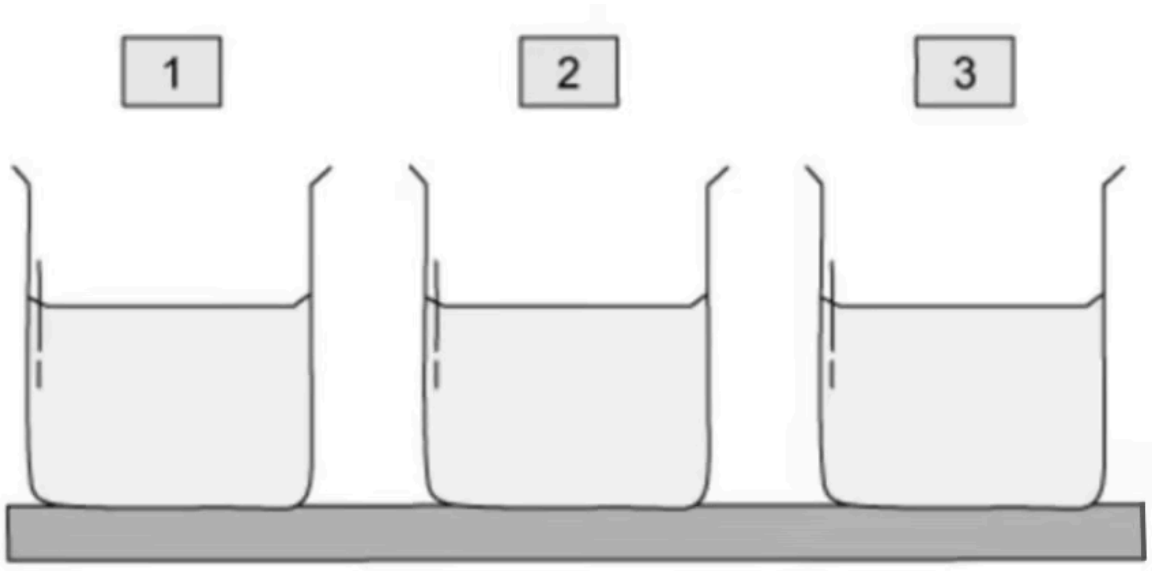
Easy Questions

1 (a) A student had three different solutions in beakers **1**, **2** & **3** as shown in **Figure 1**.

Figure 1



The beakers contained one of the following solutions but the student did **not** know which beaker contained each solution.

- potassium bromide
- calcium sulfate
- copper nitrate

To identify the solutions, the student performed a flame test.

Describe how to carry out a flame test.

Answer

A flame test can be carried out by:

- Use a clean (nichrome/platinum) wire
  Allow clean the wire with acid (and heat it)
  Ignore "splint" or "spray"

- Dip the wire in the sample and hold in a blue / roaring flame
  Allow non-luminous flame
  Do not accept "yellow" or "safety" flame

[Total: 2 marks]

- The wire must be clean before introducing it into the flame otherwise the wire could be contaminated with a previous sample
- This would mean that the colour of the sample being tested would be masked by the contaminant and the correct colour would not be seen
- The wire can be cleaned by dipping it into dilute acid and putting it into the flame until the flame does not change colour

(2 marks)

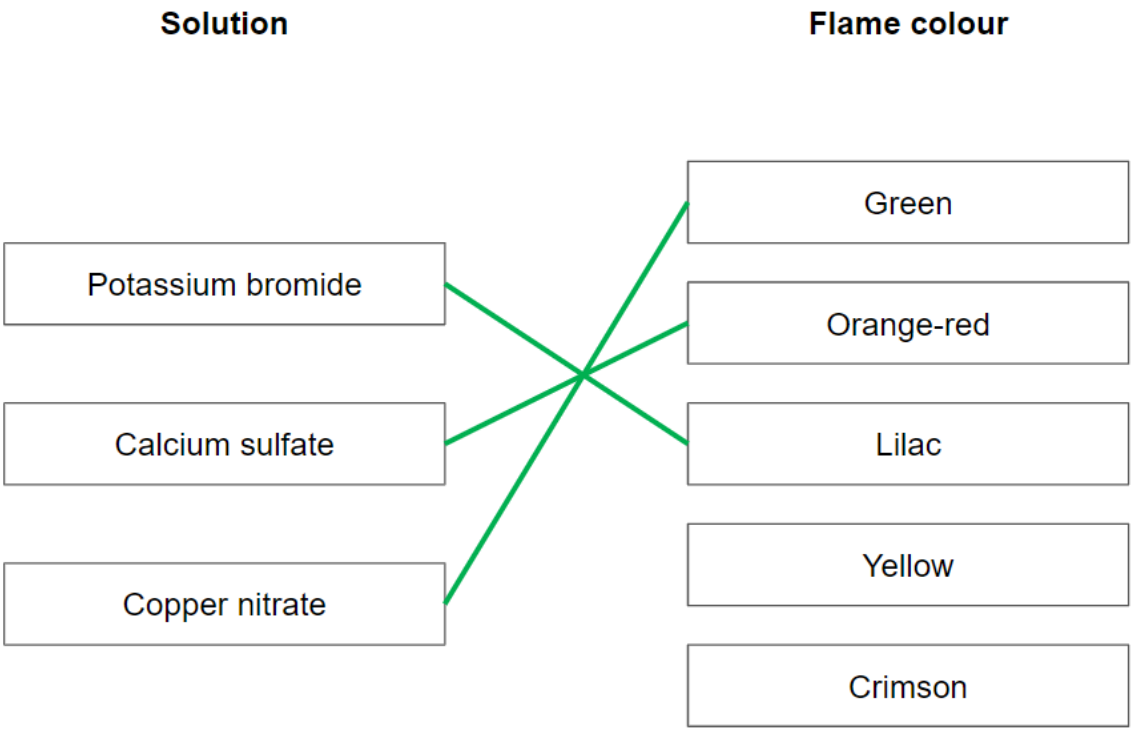
(b) The student recorded the flame colour that was observed with the solutions in beakers **1**, **2** and **3**.

Draw **one** line from each solution to the colour of the flame that it would produce.

Solution	Flame colour
Potassium bromide	Green
Calcium sulfate	Orange-red
Copper nitrate	Lilac
	Yellow
	Crimson

Answer

The correct colours for each solution are:



- Potassium bromide - lilac; [1 mark]
- Calcium sulfate - orange-red; [1 mark]
- Copper nitrate - green; [1 mark]

[Total: 3 marks]

(3 marks)

(c) The student wanted to confirm the identity of the solutions in beakers **1**, **2** and **3** so performed further tests on the solutions.

They added dilute nitric acid followed by barium nitrate solution to each of the solutions.

Which of the solutions would produce a white precipitate?

Tick (✓) **one** box.

Potassium bromide	
Calcium sulfate	
Copper nitrate	

Answer

The solution that would produce a white precipitate is:

Potassium bromide	
Calcium sulfate	✓; [1 mark]
Copper nitrate	

[Total: 1 mark]

- Adding dilute nitric acid removes any unwanted ions, e.g. carbonate ions, which would also produce a white precipitate when barium nitrate was added
    - **Tip**: avoid general comments such as nitric acid removes impurities; this may not be sufficient to gain a mark
- A white precipitate will be produced if the solution contains sulfate ions as insoluble barium sulfate is produced:
    - Ba^{2+} (aq) + SO_4^{2-} (aq) → $BaSO_4$ (s)
- This test can also be performed by adding dilute hydrochloric acid followed by barium chloride solution

(1 mark)

(d) The student added dilute nitric acid and silver nitrate solution to each of the solutions.

Which solution would produce a cream precipitate?

Tick (✓) **one** box.

Potassium bromide	
Calcium sulfate	
Copper nitrate	

Answer

The solution that would produce a cream precipitate is:

Potassium bromide	✓; [1 mark]
Calcium sulfate	
Copper nitrate	

[Total: 1 mark]

- Dilute nitric acid is added to remove unwanted ions, e.g. carbonate ions which would form a precipitate with silver nitrate
- Silver ions react with bromide ions to form insoluble silver bromide which is a cream precipitate:
  - Ag^{+} (aq) + Br^{-} (aq) → AgBr (s)
- **Careful:** Dilute hydrochloric acid should not be used in this test as the chloride ions from the acid would react with the silver ions producing the white precipitate silver chloride

(1 mark)

(e) Finally, the student added a few drops of sodium hydroxide solution to each of the solutions.

Which solution would form a white precipitate?

Tick (✓) **one** box.

Potassium bromide	
Calcium sulfate	
Copper nitrate	

Answer

The solution that would produce a white precipitate is:

Potassium bromide	
Calcium sulfate	✓; [1 mark]
Copper nitrate	

[Total: 1 mark]

- Insoluble calcium hydroxide is formed which is a white precipitate
  - Ca^{2+} (aq) + $2OH^-$ (aq) → $Ca(OH)_2$ (s)

(1 mark)

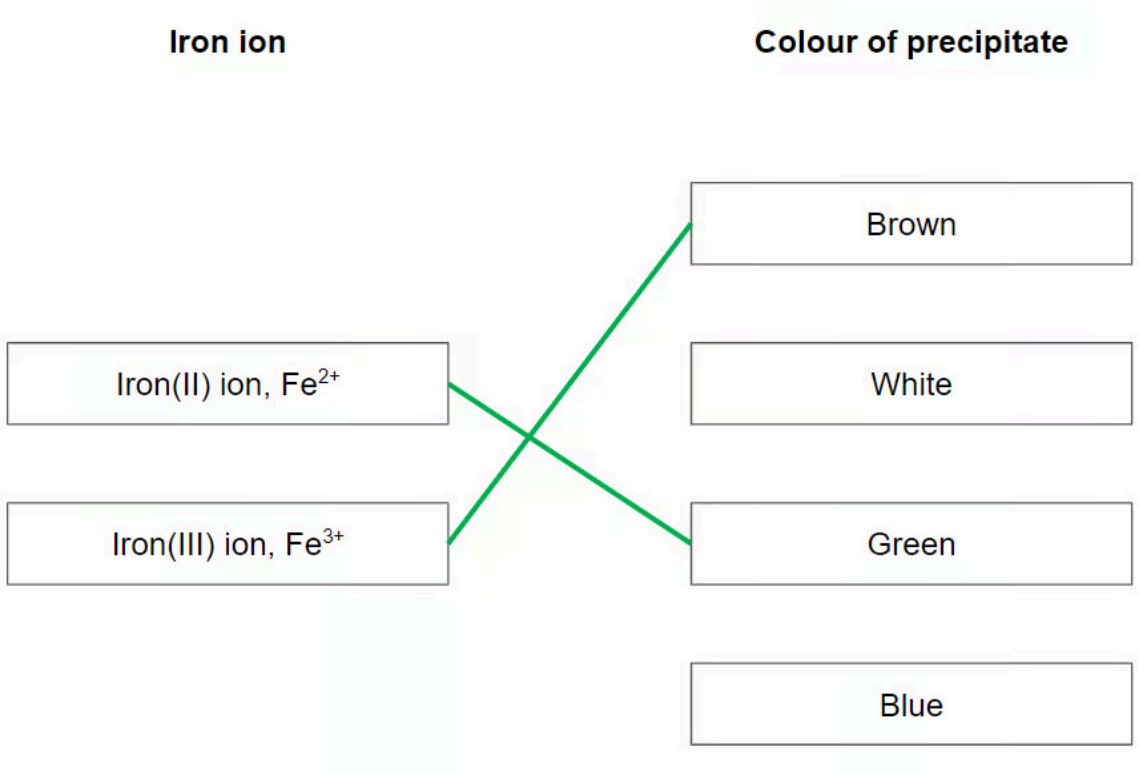
2 (a) Solutions containing iron(II) ions, Fe^{2+}, and iron(III) ions, Fe^{3+}, will produce precipitates when sodium hydroxide solution is added to them.

Draw **one** line from the iron ion to the colour of the precipitate formed.

Iron ion	Colour of precipitate
	Brown
Iron(II) ion, Fe^{2+}	White
Iron(III) ion, Fe^{3+}	Green
	Blue

Answer

The colour of the precipitates formed is:



- Iron(II) ions, Fe^{2+} - green; [1 mark]
- Iron(II) ions, Fe^{3+} - brown; [1 mark]

[Total: 2 marks]

- Fe^{2+} is always linked to green and Fe^{3+} to brown
- Fe^{3+} is the ion responsible for rust which can help you remember the colour of the ion

(2 marks)

(b) Sodium hydroxide solution was added to another solution which contained metal ions.

A white precipitate was formed.

Which of the following ions could **not** be the metal ion.

Tick (✓) **one** box.

Copper	
Magnesium	
Aluminium	
Calcium	

Answer

The metal ion which could not be in the solution is:

Copper	✓; [1 mark]
Magnesium	
Aluminium	
Calcium	

[Total: 1 mark]

- Copper ions produce a blue precipitate with sodium hydroxide which is copper hydroxide
- All the other metal ions produce a white precipitate

(1 mark)

(c) An excess of sodium hydroxide was added to the solution part b) and the white precipitate dissolved.

Which of the ions is the metal ion in solution?

Tick (✓) **one** box,

Copper	
Magnesium	
Aluminium	
Calcium	

Answer

The metal ion in solution is:

Copper	
Magnesium	
Aluminium	✓; [1 mark]
Calcium	

[Total: 1 mark]

- When a few drops of sodium hydroxide is added to aluminium ions, the white precipitate of aluminium hydroxide is produced
- When an excess of sodium hydroxide is added, aluminium hydroxide dissolves forming a colourless solution

(1 mark)

(d) More than one metal ion produces a white precipitate that does not dissolve when sodium hydroxide is added in excess.

Suggest a method of distinguishing between these ions.

Answer

A suitable way to distinguish between the metal ions would be:

- Carry out a flame test
  OR
  Flame emission spectroscopy; [1 mark]

[Total: 1 mark]

- Calcium ions and magnesium ions both produce a white precipitate with sodium hydroxide that doesn't dissolve in excess sodium hydroxide
- Calcium ions result in an orange-red flame in a flame test
- Magnesium ions do not give colour to a flame (you are not expected to know this result)
- Flame emission spectroscopy can also be used to identify metal ions

(1 mark)

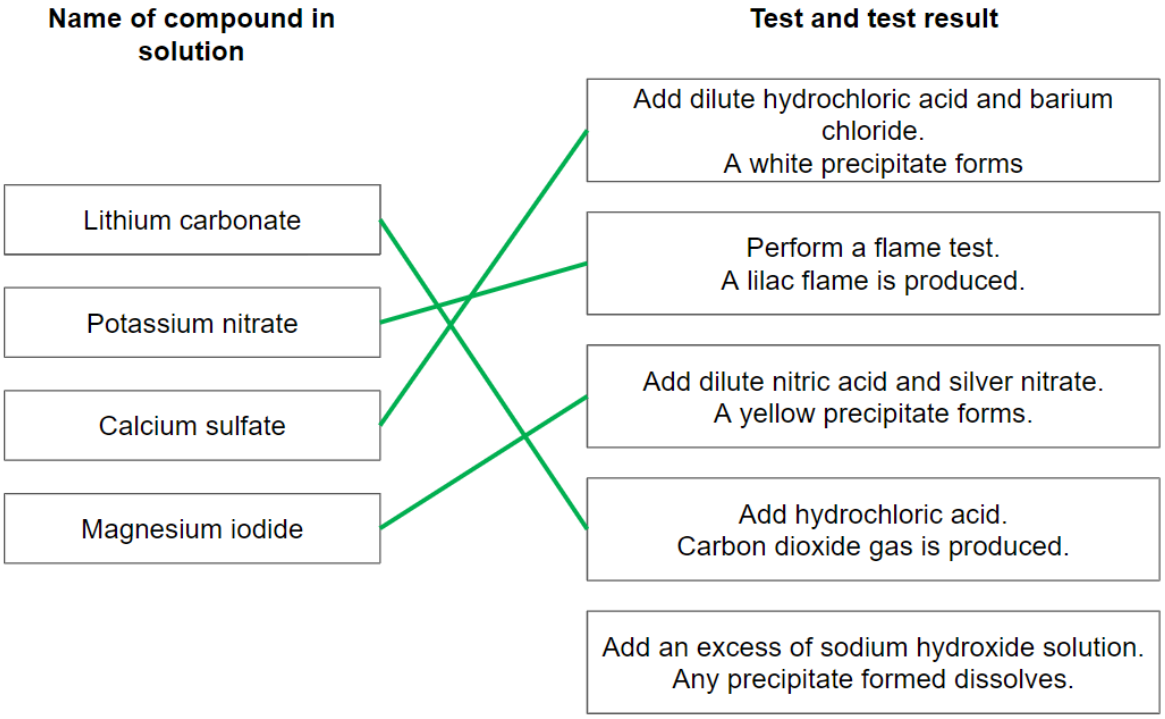
3 (a) A student wanted to find the identity of different chemical compounds in solution.

Draw **one** line from each of the compounds they tested to the test and corresponding result.

Name of compound in solution	Test and test result
Lithium carbonate	Add dilute hydrochloric acid and barium chloride. A white precipitate forms
Potassium nitrate	Perform a flame test. A lilac flame is produced.
Calcium sulfate	Add dilute nitric acid and silver nitrate. A yellow precipitate forms.
Magnesium iodide	Add hydrochloric acid. Carbon dioxide gas is produced.
	Add an excess of sodium hydroxide solution. Any precipitate formed dissolves.

Answer

The correct tests and results for the different compounds are:



- Lithium carbonate - Add hydrochloric acid. Carbon dioxide is produced; [1 mark]
- Potassium nitrate - Perform a flame test. A lilac flame is produced; [1 mark]
- Calcium sulfate - Add dilute hydrochloric acid and barium chloride. A white precipitate forms; [1 mark]
- Magnesium iodide - Add dilute nitric acid and silver nitrate. A yellow precipitate forms; [1 mark]

[Total: 4 marks]

- The remaining test and result would be the correct test and result for aluminium ions
- Aluminium will form a white precipitate with a few drops of sodium hydroxide
- The precipitate dissolves when excess sodium hydroxide solution is added
- A colourless solution is formed

(4 marks)

(b) The presence of carbon dioxide gas can be determined by a test.

Circle **one** word/ phrase from each box to complete the sentences.

Bubble the gas through

barium chloride.
dilute hydrochloric acid.
limewater.

If carbon dioxide is present it will

form a yellow precipitate.
turn cloudy.
form a blue solution.

Answer

The correct words are:

- Bubble the gas through **limewater**; [1 mark]
- If carbon dioxide is present it will **turn cloudy**; [1 mark]

[Total: 2 marks]

- If you are asked to describe how to test for carbon dioxide, make sure that you talk about bubbling the gas through limewater
- Not mentioning this and just saying "limewater goes cloudy" could cost you a mark

(2 marks)

(c) Another solution containing copper ions was tested using a flame test.

What colour flame would you expect to see?

Answer

You would expect the flame to be:

- Green; [1 mark]

[Total: 1 mark]

(1 mark)

4 (a) A student had the three potassium halide solutions shown below:

- potassium chloride
- potassium bromide
- potassium iodide

What should they add to the solutions to identify each of these solutions?

Tick (✓) **one** box.

Dilute hydrochloric acid followed by barium chloride	
Dilute nitric acid followed by barium nitrate	
Dilute hydrochloric acid followed by silver nitrate	
Dilute nitric acid followed by silver nitrate	

Answer

The student should add:

Dilute hydrochloric acid followed by barium chloride	
Dilute nitric acid followed by barium nitrate	
Dilute hydrochloric acid followed by silver nitrate	
Dilute nitric acid followed by silver nitrate	✓; [1 mark]

[Total: 1 mark]

- For this test, using hydrochloric acid is not suitable as this would introduce chloride ions which would form a precipitate with chloride ions
- Barium chloride / nitrate are used to test for sulfate ions as they form the white precipitate barium sulfate

(1 mark)

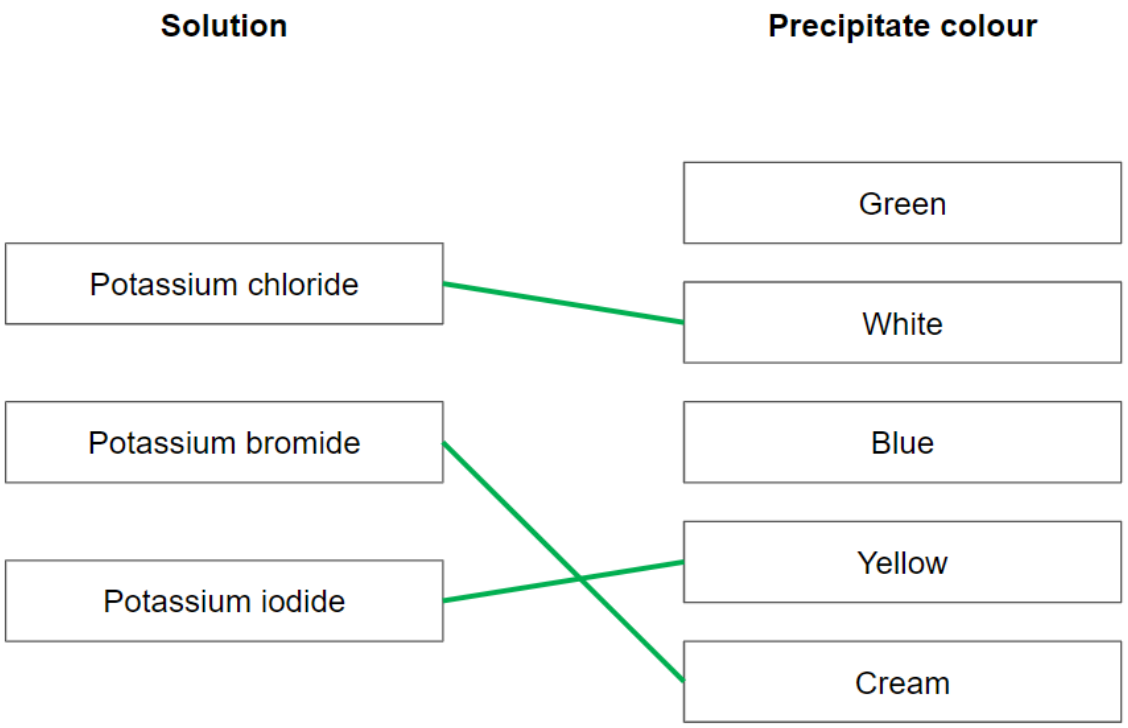
(b) When tested with the correct reagent, halides produce distinctive coloured precipitates which can be used to distinguish them from each other.

Draw **one** line from each of the potassium halide solutions to the colour of the precipitate it forms.

Solution	Precipitate colour
Potassium chloride	Green
Potassium bromide	White
Potassium iodide	Blue
	Yellow
	Cream

Answer

The correct colour precipitates formed are:



- Potassium chloride - white; [1 mark]
- Potassium bromide - cream; [1 mark]
- Potassium iodide - yellow; [1 mark]

[Total: 3 marks]

- **Remember**: The colour of the precipitate gets darker as you go down the group:
    - Chloride forms the lightest colour precipitate (white) as chlorine is the highest in the group from chlorine, bromine and iodine
    - Iodide form the darkest colour precipitate (yellow) as iodine is the lowest element in the group from chlorine, bromine and iodine

(3 marks)

(c) The student also had a solution of potassium carbonate.

What could they add to this solution to identify the carbonate ion?

What would they observe?

They should add _____.

They would observe _____.

Answer

The student should:

- Add (dilute) acid; [1 mark]
    - *accept any named acids*
- They would see effervescence / bubbling / fizzing; [1 mark]

[Total: 2 marks]

- When dilute acid reacts with a carbonate, it fizzes as carbon dioxide gas is produced, e.g.:
    - potassium carbonate + hydrochloric acid → potassium chloride + water + carbon dioxide
- The carbon dioxide can be identified by bubbling it through limewater
    - If carbon dioxide is present, limewater will turn cloudy

(2 marks)

(d) The student could perform a flame test to confirm the presence of potassium ions in the solution in part c).

What colour flame would be seen?

Tick (✓) **one** box.

Orange-red	
Blue	
Lilac	
Yellow	

Answer

The colour flame would be:

Orange-red	
Blue	
Lilac	✓; [1 mark]
Yellow	

[Total: 1 mark]

(1 mark)

5 (a) Instrumental analysis can be used to analyse elements and compounds.

Give **two** advantages of using instrumental analysis over chemical tests.

Answer

Advantages of instrumental methods are:

Any **two** from:

- Faster; [1 mark]
- More sensitive; [1 mark]
- More accurate; [1 mark]
- Can analyse mixture; [1 mark]
- Uses very small samples; [1 mark]

[Total: 2 marks]

- You do not need to learn all of these reasons but it is best to learn 2 advantages

(2 marks)

(b) Flame emission spectroscopy is an example of an instrumental method that can be used to analyse metal ions in solution.

Circle a word/phrase in each box to complete the sentences below.

The sample to be tested is put into a

flame.
solution.
beaker.

The light given out is put through a

mass spectrometer.
spectroscope.
coloured filter.

The output is called a line

graph.
chromatogram.
spectrum.

Answer

The correct words are:

- The sample to be tested is put into a **flame**; [1 mark]
- The light given out is put through a **spectroscope**; [1 mark]
- The output is called a line **spectrum**; [1 mark]

[Total: 3 marks]

(3 marks)

(c) In addition to being able to identify the metal ions in solution, what other piece of information can flame emission spectroscopy tell us about the sample?

Answer

Flame emission spectroscopy can also tell us about:

- The concentration of metal ions in solution; [1 mark]

[Total: 1 mark]

- The technique can determine the concentration as it measures the light intensity produced
- This is proportional to the number of ions in the solution
- By comparing to a standard solution of a known concentration, the concentration can be determined

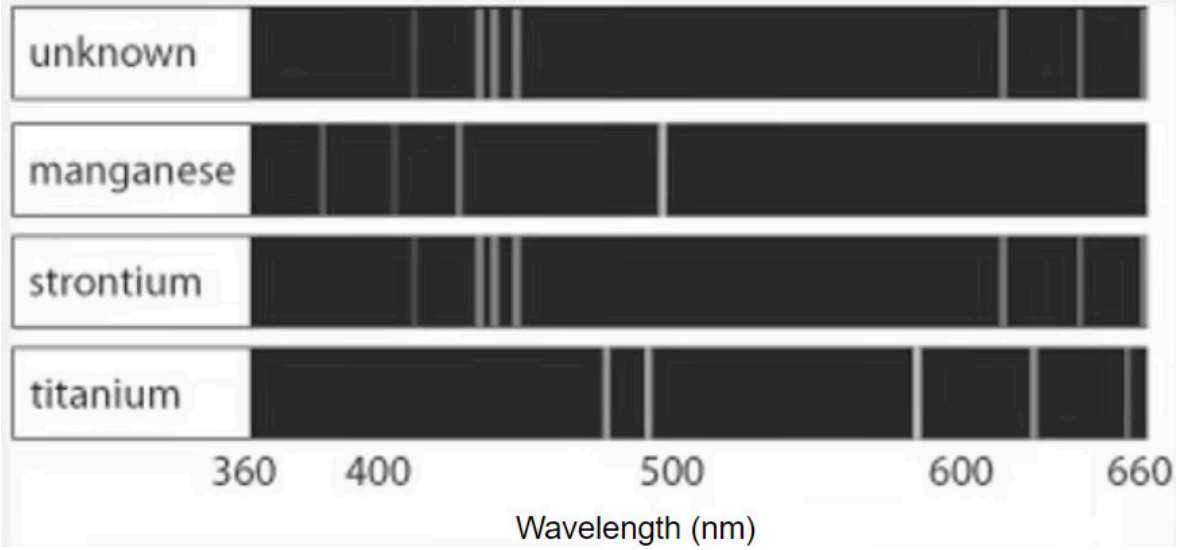
(1 mark)

(d) The resulting output from a flame emission spectrometer can be compared against those of known metals.

Figure 1 shows the output for manganese, strontium, titanium and an unidentified solution.

Using the output in **Figure 1**, identify which metal ion is present in the unidentified solution.

Figure 1



Answer

The metal present in the unidentified solution is:

- Strontium; [1 mark]

[Total: 1 mark]

- By comparing the line spectra of the unknown sample to the reference metals, it can be seen that the lines appearing in the unidentified sample match up with those lines in the spectrum of strontium

(1 mark)

6 Which is **not** an advantage of using instrumental methods rather than small-scale lab methods for identifying ions?

A. Instrumental methods are more accurate

B. Instrumental methods are faster

C. Instrumental methods are cheaper

D. Instrumental methods are more sensitive

Answer

The correct answer is C because:

- Instrumental methods use more advanced equipment that is more expensive than small-scale lab tests
- This cost is offset by the benefits of instrumental analysis being faster, more accurate and more sensitive

(1 mark)

Medium Questions

1 (a) This question is about the chemicals that are used to make fireworks.

The metal ions present in the chemicals of fireworks are what produce coloured flames.

What colour flame is produced by sodium ions?

Answer

The flame that sodium ions produce is:

- Yellow; [1 mark]
    - *allow orange or orange-yellow*

[Total: 1 mark]

(1 mark)

(b) Name a metal ion that produces a green flame.

Answer

An ion that produces a green flame is:

- Copper ion; [1 mark]
    - *allow Cu^{2+} or copper(II), barium ion or Ba^{2+}*

[Total: 1 mark]

(1 mark)

(c) A company wanted to produce fireworks with a bright red colour.

Which metal would be most suitable?

Answer

A suitable ion would be:

- Lithium; [1 mark]
    - *allow lithium ion or Li^+*

[Total: 1 mark]

(1 mark)

(d) The same company also wanted to produce fireworks with a lilac colour to mimic a flower.

Which metal would be most suitable?

Answer

A suitable ion would be:

- Potassium; [1 mark]
    - *allow potassium ion or K^+*

[Total: 1 mark]

(1 mark)

(e) Complete **Table 1** below about four chemicals.

Table 1

Chemical	Colour produced in firework
barium chloride	green
_____ carbonate	crimson
_____ sulfate	orange-red
sodium nitrate	_____

Answer

The missing words are:

Chemical	Colour produced in firework
barium chloride	green
lithium; [1 mark] carbonate	crimson
calcium; [1 mark] sulfate	orange-red
sodium nitrate	**yellow / orange-yellow / orange;** [1 mark]

[Total: 3 marks]

(3 marks)

(f) Some fireworks contain a mixture of two or more metal ions.

Why is it difficult to identify the metal ions using a flame test?

Answer

It is difficult to identify the metal ions because:

- The flame colours are masked; [1 mark]
- As the colours mix; [1 mark]
- And so, individual colours, and hence individual metal ions, cannot be distinguished; [1 mark]

[Total: 3 marks]

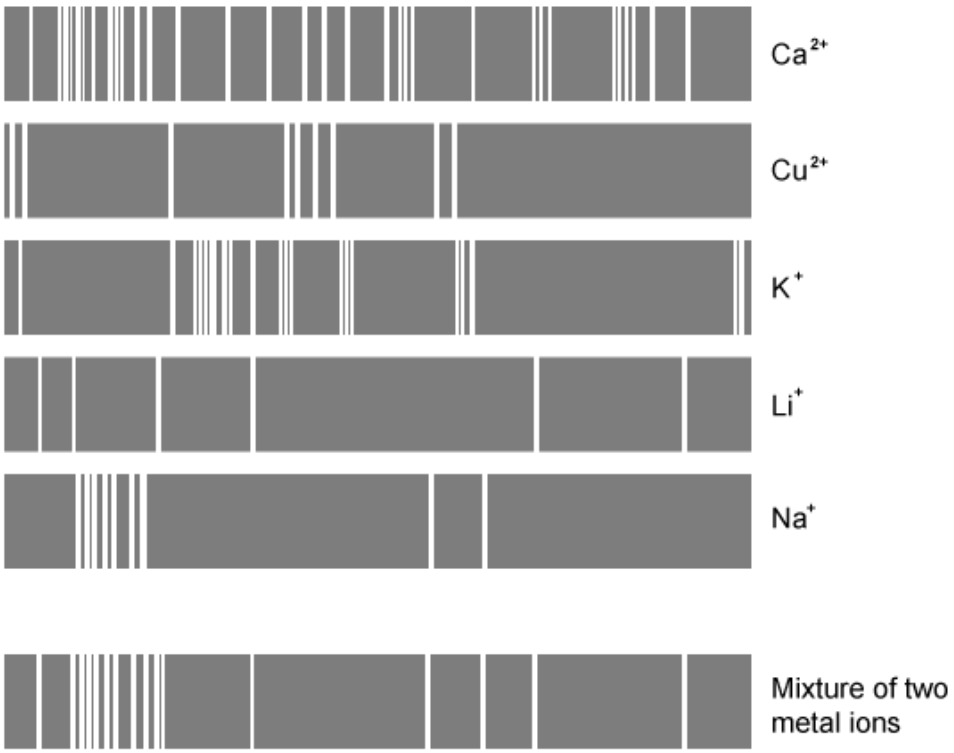
(3 marks)

(g) Flame emission spectroscopy can be used instead of flame tests to identify metal ions in a firework.

Figure 1 shows the results of flame emission spectra of five individual metal ions.

It also shows a flame emission spectrum for a mixture of two different metal ions.

Figure 1



Identify **two** metal ions that are in the mixture?

Tick two boxes.

Li^+	
Cu^{2+}	
Na^+	
Fe^{2+}	
K^+	

Answer

The two ions present are:

- Li^+; [1 mark]
- Na^+; [1 mark]

[Total: 2 marks]

(2 marks)

(h) Typically, the compounds used in fireworks also contain non-metal ions.

A scientist tests a sample from a batch of fireworks.

Silver nitrate and dilute nitric acid are added to a solution of the sample and a cream precipitate is formed.

Identify the ion present.

Answer

The ion present is:

- Bromide ion / Br^-; [1 mark]
    - *do not allow bromine*

[Total: 1 mark]

- The cream precipitate is insoluble silver bromide

(1 mark)

(i) Describe a test to detect the presence of sulfate ions in the solution and the result you would expect to see if they were present.

Answer

The test for sulfate ions is:

- Add a solution of barium chloride; [1 mark]
- Then add hydrochloric acid / HCl or nitric acid / HNO_3; [1 mark]
    - *Do not accept sulfuric acid*
- White precipitate produced; [1 mark]

[Total: 3 marks]

- If sulfuric acid was used it would contaminate the results as it contains the sulfate ion
- The white precipitate formed is insoluble barium sulfate

(3 marks)

2 Scientists test a solution of compound X.

Table 1 shows their results.

Table 1

Test	Result
Add dilute nitric acid followed by silver nitrate solution	White precipitate
Add sodium hydroxide solution	Green precipitate

Which two ions are present in compound X?

A. Fe^{3+} and Cl^-

B. Fe^{3+} and SO_4^{2-}

C. Fe^{2+} and Cl^-

D. Fe^{2+} and SO_4^{2-}

Answer

The correct answer is C because:

- When sodium hydroxide solution is added to Fe^{2+} ions, a green precipitate of $Fe(OH)_2$ is formed
- When dilute nitric acid and then silver nitrate solution are added to Cl^- ions, a white precipitate of AgCl is formed

A & **B** are incorrect as Fe^{3+} forms a brown precipitate when sodium hydroxide solution is added

B & **D** are incorrect as SO_4^{2-} forms a white precipitate when a barium solution is added

(1 mark)

3 Scientists test a solution from a bottle that is known to contain a copper (II) compound.

Table 1 shows their results.

Table 1

Test	**Result**
Flame test	Yellow flame
Add sodium hydroxide solution	Blue precipitate formed
Add dilute nitric acid followed by silver nitrate solution	Yellow precipitate formed

Which statement below is **true**?

A. The flame test was performed incorrectly

B. Bromide ions are present, so the compound is $CuBr_2$

C. The test tube was contaminated for the sodium hydroxide test

D. The copper compound in the bottle was contaminated with another metal compound

Answer

The correct answer is D because:

- The solution is contaminated by a sodium compound, which is what gave the yellow flame and masked the colour of the green flame of the copper (II) ions

A is incorrect as the flame test was accurate but the sodium colour easily masked the copper colour

B is incorrect as the yellow precipitate formed when nitric acid and silver nitrate were added was from iodide ions, not bromide ions

C is incorrect as the sodium hydroxide test gave the correct results of a blue precipitate to show that copper (II) ions were present

(1 mark)

4 (a) A student investigated the composition of an egg shell as part of a wider study.

The student performed some tests on the egg shell and recorded the results as shown in **Table 2** below.

Table 2

	Test	Observation
1	Dilute HCl was added to the shell	A gas was produced. The egg shell dissolved and formed a colourless solution.
2	A flame test was done on the colourless solution from test **1**.	The flame turned red.
3	NaOH solution was added to the colourless solution from test **1**.	A white precipitate formed that did not dissolve in excess NaOH solution.
4	$AgNO_3$ solution was added to the colourless solution from test **1**.	A white precipitate formed.

The student concluded that there were carbonate ions present in the egg shell.

Describe a test the student could use to identify the gas produced in test **1**.

Answer

A test to identify the gas produced in test **1** is:

- Bubble the gas through lime water / a solution of calcium hydroxide; [1 mark]
- The solution turns milky / cloudy if there are carbonate ions present; [1 mark]

[Total: 2 marks]

- When an acid reacts with a carbonate, a salt, water and carbon dioxide are produced

(2 marks)

(b) The student concluded that the egg shell also contains aluminium ions.

Is this conclusion correct?

Use the results in the table to justify your answer.

Answer

The results show:

- The red flame indicates that either calcium / lithium ions are present; [1 mark]
- Calcium / magnesium would also produce a white precipitate with NaOH; [1 mark]
- The precipitate formed in test **3** / by adding sodium hydroxide solution would dissolve in excess if aluminium ions were present; [1 mark]
- Therefore the conclusion is incorrect; [1 mark]

[Total: 4 marks]

- **Remember** that aluminium ions have no flame colour

(4 marks)

(c) The student concluded that the egg shell also contains chloride ions.

Is this conclusion correct?

Use the results in the table to justify your answer.

Answer

The results show:

- A white precipitate is formed in test **4 /** by adding silver nitrate; **[1 mark]**
- But chloride ions are in hydrochloric acid; [1 mark]
- Therefore the conclusion is incorrect; [1 mark]

[Total: 3 marks]

- **Careful:** Hydrochloric acid was added in test **1** so a positive result for chloride ions doesn't mean that they came from the shell

(3 marks)

(d) A group of scientists working on a similar project as the student wanted to investigate the amount of lead found in egg shells.

Instead of using older methods, they used a modern instrumental method which was *more sensitive*.

Name **one** modern instrument which is used to identify elements.

Answer

A modern instrument used to identify elements is:

- **EITHER**

Mass spectrometry

OR

Atomic absorption spectroscopy; [1 mark]

[Total: 1 mark]

(1 mark)

(e) What does the term *more sensitive* mean?

Answer

More sensitive means:

- Ability to detect a much smaller amount of the substance; [1 mark]
    - *allow can detect smaller changes or smaller sample sizes*
    - *do **not** accept detects a small amount of substance*

[Total: 1 mark]

- **Careful:** This does need to comparative statement as the word *more* is used

(1 mark)

(f) State **two** other advantages of modern instrumental methods over older methods?

Answer

Advantages of modern instruments are:

- Modern instruments are more accurate; [1 mark]
- Modern instruments are simpler and quicker to use; [1 mark]

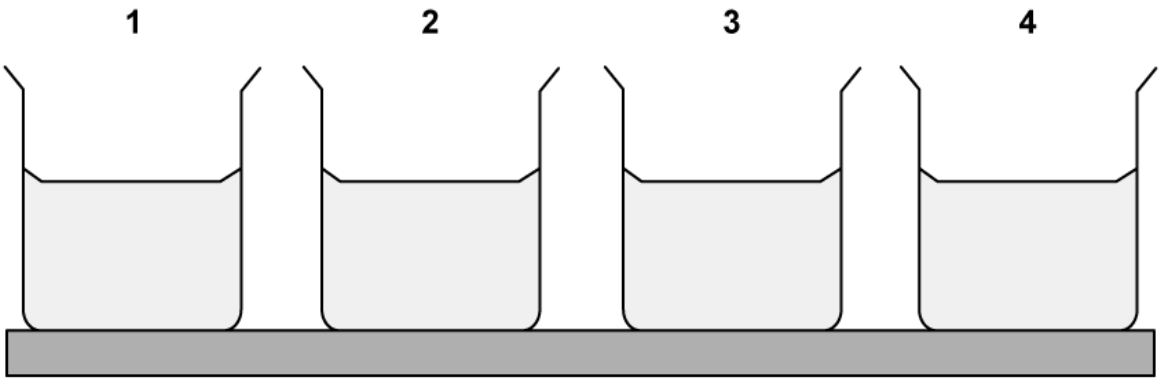
[Total: 2 marks]

- **Careful:** You do not get a mark for stating that modern instruments are more sensitive as this has already been given to you in the question

(2 marks)

5 Four different colourless solutions were given to a group of students in beakers **1, 2, 3** and **4**, shown in **Figure 3**.

Figure 3



The students knew that the solutions were

- sodium carbonate
- sodium iodide
- sodium chloride
- potassium carbonate

but did **not** know which solution was in which beaker.

The teacher asked the class to plan a method that could be used to identify each solution.

The teacher suggested using a flame test to identify the positive ions and provided them with the following reagents only:

- silver nitrate solution
- dilute nitric acid

Write a method the students could use to identify the four solutions.

You should include the results of the tests you describe.

Answer

Suitable tests and accompanying results are:

- **Test:** use platinum **/** nichrome wire for the flame test; [1 mark]
- **Result:** the sodium compounds result in a yellow / yellow-orange / orange flame

OR

The potassium compound results in a lilac / purple flame; [1 mark]

- *allow potassium carbonate gives a different colour to the three sodium compounds*
- **Test:** add dilute nitric acid to all four solutions; [1 mark]
- **Result:** sodium carbonate and potassium carbonate will effervesce

OR

Sodium chloride and sodium iodide will not effervesce; [1 mark]

- **Test:** add dilute nitric acid followed by silver nitrate; [1 mark]
- **Result:** sodium chloride and sodium iodide produce a precipitate

OR

Sodium chloride produces a white precipitate and sodium iodide produces a yellow precipitate; [1 mark]

- *accept sodium carbonate and potassium carbonate do not produce a precipitate*

[Total: 6 marks]

- **Tip:** Nitric acid is used so that the solutions are not contaminated with unwanted ions which would give a false positive with some tests, e.g. if hydrochloric acid was used, the silver nitrate test would give a positive result as the chloride would react with the silver ions to form a white precipitate of solver chloride

(6 marks)

6 A compound is suspected of containing calcium ions, Ca^{2+}.

Which test would **not** help to positively identify calcium?

	Test	**Result**
A	Flame test	Orange-red flame
B	Add sodium hydroxide solution	White precipitate forms
C	Add nitric acid and silver nitrate	White precipitate forms
D	Flame emission spectroscopy	Characteristic lines match the reference spectrum

Answer

The correct answer is C because:

- Calcium ions can be identified by
  - Orange-red colour in a flame test
  - White precipitate when sodium hydroxide solution is added as $Ca(OH)_2$ is formed

- The lines on a flame emission spectrum match with the reference spectrum for calcium

- The test with nitric acid and silver nitrate is a test for halide ions, and a white precipitate would indicate the presence of chloride ions, not calcium ions

(1 mark)

7 Calcium carbonate can react with hydrochloric acid by the following equation:

$$\mathbf{CaCO_3\,(s) + 2HCl\,(aq) \rightarrow CaCl_2\,(aq) + H_2O\,(l) + CO_2\,(g)}$$

Which observation does **not** tell you that this reaction has occurred?

	Test	**Result**
A	Add dilute nitric acid then by silver nitrate solution	White precipitate forms
B	Bubble any gases present through limewater	Limewater turns cloudy
C	Observe the solutions when they are mixed	Solutions bubble and fizz upon mixing
D	Test pH of the solution at the start and after 30 s	pH increases

Answer

The correct answer is A because:

- Adding dilute nitric acid and silver nitrate will form a white precipitate in the presence of chloride ions

- These ions are present in both the reactants (HCl) and the products ($CaCl_2$) and so the formation of this precipitate is therefore not an indication that the reaction has occurred

B is incorrect as the carbon dioxide produced will turn limewater cloudy

C is incorrect as the production of carbon dioxide gas will make the solutions bubble and fizz when mixed

D is incorrect as the hydrochloric acid will get used up during the reaction and the pH will increase

(1 mark)

Hard Questions

1 (a) A student was asked to identify the ions present in three different solutions of compounds, **A**, **B** and **C**.

The student's results from a series of tests on each solution are shown in **Table 1**.

Table 1

Compound	Test				
	Flame Test	**Add dilute hydrochloric acid**	**Add sodium hydroxide solution**	**Add dilute hydrochloric acid and barium chloride**	**Add dilute nitric acid and silver nitrate**
A	green flame	fizzing	blue precipitate	fizzing, no precipitate	no reaction
B	red flame	no reaction	white precipitate	no reaction	cream precipitate
C	yellow flame	no reaction	no reaction	white precipitate	no reaction

Identify the **two** ions present in each of the compounds **A**, **B**, and **C**.

A: _____ and _____

B: _____ and _____

C: _____ and _____

Answer

The correct identities of the compounds **A**, **B** and **C** are:

- **A**: Cu^{2+} / copper **AND** CO_3^{2-} / carbonate; [1 mark]
    - *allow copper carbonate / $CuCO_3$*
- **B**: Ca^{2+} / calcium **AND** Br^- / bromide; [1 mark]
    - *allow calcium bromide / $CaBr_2$*
    - *do not accept bromine*
- **C**: Na^+ / sodium **AND** SO_4^{2-} / sulfate; [1 mark]
    - *allow sodium sulfate/ Na_2SO_4*

[Total: 3 marks]

- Compound **A** is copper carbonate because:
    - The flame test gives a green flame and reaction with sodium hydroxide solution produces a blue precipiate
        - Both tests show that copper ions are present
    - The test with dilute hydrochloric acid produces fizzing – this shows that carbonate ions are present
    - The carbonate ions react with the acid to form carbon dioxide gas which causes the fizzing
- Compound **B** is calcium bromide because:
    - The flame test gives a red flame which could be either lithium (produces a red colour) or calcium (produces an orange-red colour)
        - Testing with sodium hydroxide solution produces a white precipitate which means calcium ions are present as lithium would not form a precipitate
    - The test with nitric acid and silver nitrate produces a cream precipitate – this shows that bromide ions are present

        - **Remember**: The colour of the precipitate formed with silver nitrate tells you which halide ion is present
- Compound **C** is sodium sulfate because:
    - The flame test gives a yellow flame which identifies the sodium ion
    - The test with dilute hydrochloric acid and barium chloride produces a white precipitate – this shows that sulfate ions are present

(3 marks)

(b) What is the purpose of adding dilute acid in the tests with barium chloride and silver nitrate?

Answer

The purpose of adding dilute acid in the tests with barium chloride and silver nitrate is:

- To remove any carbonate ions; [1 mark]

[Total: 1 mark]

- **Careful:** It used to be enough to say "remove impurities" but, more recently, examiners are expecting the specific detail of "remove carbonate ions"

(1 mark)

(c) Suggest what could be seen if the acid was **not** added?

Answer

If dilute acid was not added before barium chloride or silver nitrate, you might see:

- A precipitate; [1 mark]
  Ignore any colours given

[Total: 1 mark]

- Carbonate compounds are generally insoluble, with some exceptions, including Group 1 carbonates
- Barium chloride will form the white precipitate, barium carbonate if carbonate ions are present
  - This would cause a false positive result when testing for sulfate ions as the expected test result is a white precipitate
- Silver nitrate will form the precipitate, silver carbonate if carbonate ions are present which would mask a positive result if halide ions were present

(1 mark)

(d) Explain why nitric acid is used before using silver nitrate instead of hydrochloric acid or sulfuric acid.

Answer

Nitric acid is used before using silver nitrate instead of hydrochloric acid or sulfuric acid because:

- Hydrochloric acid would introduce Cl^- / chloride ions; [1 mark]
- Sulfuric acid would introduce SO_4^{2-} / sulfate ions; [1 mark]
- Chloride / sulfate ions form a white precipitate with Ag^+ / silver ions; [1 mark]

[Total: 3 marks]

- Many silver compounds are insoluble so will form precipitates with many ions
- The majority of compounds containing nitrate ions are soluble which means that the nitrate ions will not produce precipitates with most metal ions and therefore will not interfere with the test for halide ions

(3 marks)

2 (a) A student had a solution of an unknown compound, **Y**.

They performed the following tests on fresh samples of the solution and recorded their observations:

Test 1:	Add sodium hydroxide solution
Observation:	Green precipitate formed
Test 2:	Add dilute nitric acid followed by silver nitrate solution
Observation:	Yellow precipitate formed

The student concluded that the formula of compound **Y** was FeI_3,

Is the student's conclusion correct?

Explain your answer.

Answer

The student's conclusion is:

- Incorrect *Stating this does not gain a mark, marks are awarded for the explanation*
- Green precipitate (with sodium hydroxide) indicates iron(II) ions / Fe^{2+}; [1 mark]
- Yellow precipitate (with silver nitrate) indicates iodide ions/ I^-; [1 mark]
- The formula for iron(II) iodide is FeI_2; [1 mark]
- FeI_3 contains iron(III) ions / Fe^{3+} **OR** FeI_3 would produce a brown precipitate (with sodium hydroxide); [1 mark]

[Total: 4 marks]

- Use the number of marks available to judge how much detail you need to give
- Make sure you comment on what each test result shows and how this compares to the student's conclusion
- If you think the conclusion is incorrect, comment on what the correct conclusion should be
- Structuring an answer such as this comes with practice

(4 marks)

(b) The student repeated **Test 1** on a solution of another compound, **Z**.

A white precipitate formed.

The student concluded that magnesium ions were present.

Explain why the student cannot make that conclusion based on the test results.

Give details of how they could use other tests to identify the metal ion present in compound **Z**.

Answer

The student cannot make that conclusion based on the test results because:

- Calcium ions / Ca^{2+} also form a white precipitate (with sodium hydroxide); [1 mark]
- Aluminium ions / Al^{3+} also form a white precipitate (with sodium hydroxide); [1 mark]

The further tests they could perform to identify the metal ion present in compound **Z** are:

- Add excess sodium hydroxide solution
  AND
  Aluminium ions / Al^{3+} will dissolve; [1 mark]
- Perform a flame test
  AND
  Calcium ions / Ca^{2+} give an orange-red flame; [1 mark]

[Total: 4 marks]

- As with part (a), think carefully about how you structure your answer
- You need to know the three ions that produce a white precipitate with sodium hydroxide solution and how to differentiate between them
- When excess sodium hydroxide is added, only the precipitate formed by aluminium ions will dissolve, precipitates formed from calcium or magnesium ions will not dissolve
- Calcium ions give a distinctive orange-red colour but magnesium ions and aluminium ions do not

- Therefore, aluminium ions and calcium ions can both be positively identified using one of the additional tests
- Out of the three ions, magnesium ions can be identified by the process of elimination using these further tests

(4 marks)

(c) The student wanted to further identify compound **Z**.

They added dilute nitric acid followed by silver nitrate solution.

Explain how the observation of a cream precipitate helps confirm the presence of bromide ions in compound Z

Answer

A cream precipitate formed when silver nitrate was added to compound **Z** because:

- Silver bromide / AgBr is formed; [1 mark]
- Which is insoluble; [1 mark]
  allow $Ag^+ (aq) + Br^- (aq) \rightarrow AgBr (s)$ *for 2 marks*

[Total: 2 marks]

- Any precipitate formed in an aqueous solution means that the compound is insoluble in water
- Remember that the colour of the precipitate formed with silver nitrate identifies the halide ion present
- The precipitate gets darker as you go down the group
- Chloride ions form the lightest precipitate (white); iodide ions form the darkest (yellow)

(2 marks)

3 (a) Minerals from a quarry were taken to a laboratory for analysis.

Four samples of minerals, **A**, **B**, **C** and **D** were submitted for identification of their ions.

In the laboratory, water is added to each mineral to form solutions and further tests are carried out.

The results of these tests are shown in **Table 1**.

Table 1

Test	A	B	C	D
Add sodium hydroxide solution	blue precipitate	no change	white precipitate	green precipitate
Add dilute hydrochloric acid	fizzed	fizzed	no change	no change
Add dilute hydrochloric acid and barium chloride	no change	no change	white precipitate	no change
Add dilute nitric acid and silver nitrate	no change	yellow precipitate	no change	cream precipitate

It was concluded that mineral **B** contained two negative ions and the positive ion was unidentified.

How do the results show this?

Answer

The results show that mineral **B** contains two negative ions and the positive ion was unidentified because:

- It fizzes with dilute hydrochloric acid indicating carbonate ions / CO_3^{2-}; [1 mark]

- With silver nitrate, a yellow precipitate was formed indicating iodide ions / I^-; [1 mark]
  Iodine is not accepted

- There was no change with sodium hydroxide solution which is the test for some positive / metal ions; [1 mark]

[Total: 3 marks]

- Exam technique should guide you here
- Three marks and the question talks about two negative ions and one positive ion
  - In theory, one mark per ion

(3 marks)

(b) It was believed that the positive ion present in mineral **B** was potassium.

Describe a further test, including the expected result, that could be used to confirm the presence of potassium ions.

Answer

A further test that could be used to confirm the presence of potassium ions and the expected results are:

- Test: (Carry out a) flame test; [1 mark]
- Expected results: a lilac flame; [1 mark]

[Total: 2 marks]

- Potassium being dropped in water is a demonstration that you have probably seen in the classroom
- Lilac is the most commonly given colour for the flame produced by potassium ions

(2 marks)

(c) Mineral **C** formed a white precipitate with sodium hydroxide solution.

One metal ion that gives a white precipitate with sodium hydroxide solution is aluminium.

Name **two** other metal ions that would also produce a white precipitate.

Answer

The two other metal ions that would produce a white precipitate with sodium hydroxide solution are:

- Calcium / Ca^{2+}
  AND
  Magnesium / Mg^{2+}; [1 mark]
  Allow any other metal ions that would give a white precipitate, e.g. zinc, lead
  Two correct metals are required to score 1 mark

[Total: 1 mark]

(1 mark)

(d) State an instrumental method that could be used to distinguish between the three metal ions from part (c).

Answer

An instrumental method that could be used to distinguish between the three metals is:

- Flame emission spectroscopy; [1 mark]

[Total: 1 mark]

(1 mark)

(e) Identify the ions in minerals **A** and **D**.

Answer

The ions in minerals **A** and **D** are:

- Mineral **A**: Copper ions / Cu^{2+}
  AND
  Carbonate ions / CO_3^{2-}; [1 mark]

- Mineral **D**: Iron(II) ions; Fe^{2+}
  AND
  Bromide ions / Br^-; [1 mark]
  *Do **not** allow bromine ions*

[Total: 2 marks]

- For mineral **A**
  - The blue precipitate formed with sodium hydroxide solution indicates copper ions
    - The precipitate is copper hydroxide
  - Fizzing with hydrochloric acid indicates carbonate ions are present as the metal carbonate is neutralised and carbon dioxide gas is given off
- For mineral **D**
  - The green precipitate formed with sodium hydroxide solution indicates iron(II) ions
    - The precipitate is iron(II) hydroxide
  - The cream precipitate formed with silver nitrate indicates bromide ions are present
    - The cream precipitate is insoluble silver bromide

(2 marks)

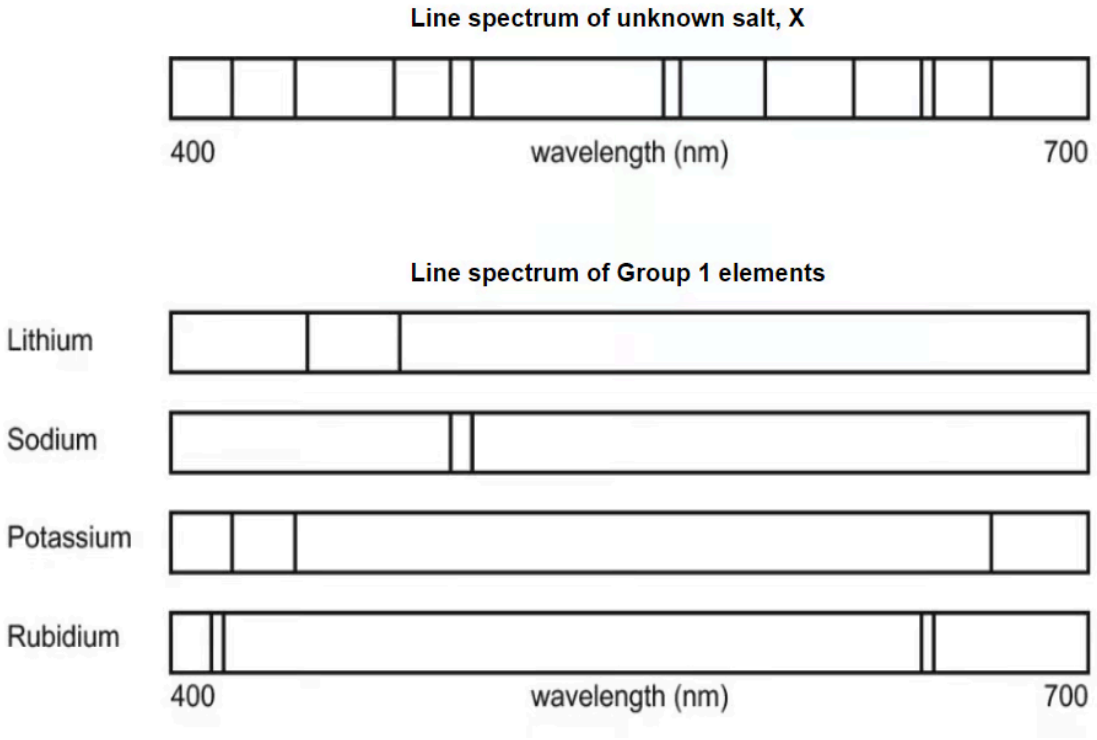
4 (a) An unknown salt sample, **X**, has been sent off for analysis for identification.

A small sample of the unknown salt, **X**, is put into a flame emission spectroscope and its line spectrum is generated.

The line spectrum is compared to the line spectrum of Group 1 elements to see if the metal ion present in **X** can be identified.

The line spectra are shown in **Figure 1**.

Figure 1



State which elements are or are not present in the unknown salt sample, **X**.

Give reasons for your answers.

Answer

The elements present and not present are:

- Present: Sodium **AND** potassium **AND** unknown(s); [1 mark]
- Not present: Lithium **AND** rubidium; [1 mark]

- For elements present: Lines are in same pattern / position / spectra 'match' or 'fit'; [1 mark]
- For elements not present: There is no match / partial match; [1 mark]
- For unknown elements: Some lines do not match elements given; [1 mark]

[Total: 5 marks]

- This was not an easy comparison between the spectra as there were lines in the lithium spectrum that were very close, but not the same as those in the unknown sample, so lithium could not have been present in the unknown solution
- The lines in the sample matched some, but not all of the lines of rubidium, so rubidium could not have been present
- All of the lines in the sodium and potassium spectra matched lines of the unknown sample which means these elements were present
- There were some lines in the spectrum of the unknown sample which had not been accounted for; these must belong to another, unidentified, element

(5 marks)

(b) Other than using flame emission spectroscopy, give details of any further tests that could be carried out to identify any unidentified elements.

Answer

Further tests that could be carried out to identify any unidentified elements are:

Any **two** from:

- Add sodium hydroxide solution to test for metal ions; [1 mark]
- Add silver nitrate to test for chloride / bromide / iodide / halide ions; [1 mark]
- Add barium chloride / nitrate to test for sulfate ions; [1 mark]
- Add acid to test for carbonate ions; [1 mark]

[Total: 2 marks]

(2 marks)

(c) Explain how flame emission spectroscopy produces a line spectrum.

Answer

How flame emission spectroscopy produces a line spectrum:

- The sample is put into a flame; [1 mark]
- The light given out is passed through a spectroscope (which gives out a line spectrum); [1 mark]

[Total: 2 marks]

- The chemistry behind this is quite difficult and beyond the scope of GCSE
- You do not need to explain why each element produces a unique spectrum and no more detail about how a spectroscope works is required

(2 marks)

(d) Give **two** advantages of using a flame emission spectroscopy machine, rather than chemical tests, to identify samples.

Answer

Two advantages of using an emission spectroscopy machine, rather than chemical tests, to identify samples are:

Any **two** from:

- More accurate; [1 mark]
- More sensitive / uses a smaller sample; [1 mark]
- Faster; [1 mark] *Do not allow accurate, fast or sensitive; need to be comparative statements*
- Does not rely on human judgment; [1 mark]
- Can identify a mixture of ions; [1 mark]

[Total: 2 marks]

- **Careful**: Just stating accurate, fast etc. is not sufficient to gain a mark as you need to explain why this is an advantage over chemical tests
- It is useful to learn at least 2 advantages of modern instrumental methods – the first three given here are the most suitable for you to know

(2 marks)

5 (a) Various barium compounds are used as medicines by doctors. They can be used to help diagnose problems in the stomach and bowels or for treating irregularities with the heart beating.

A medical student has a sample that they believe to be a barium compound but wants to perform some tests on the solution to confirm its identity.

They perform a flame test and a green colour flame is observed.

Table 1 shows flame colours for some other elements.

Table 1

Element	**Flame colour**
Barium	Green
Calcium	Orange-red
Copper	Green
Phosphorus	Blue-green
Potassium	Lilac
Sodium	Yellow

The student concluded that the solution did not contain calcium, potassium or sodium ions.

Explain why this is correct and give any other conclusions that the student could make from this test, giving your reasons.

Answer

The solution did not contain calcium, potassium or sodium ions because:

Any **three** from:

- The colour is missing from the flame test / not orange-red so doesn't contain calcium / not lilac so doesn't contain potassium / not yellow so doesn't contain sodium; [1 mark]
- It might contain barium
  AND
  copper as they give a green colour; [1 mark]
- Phosphorus has a similar colour / difficult to tell the colours apart; [1 mark]
- Not able to confirm the identity of the metal present as more than one metal gives a green colour; [1 mark]

[Total: 3 marks]

(3 marks)

(b) The student obtained an emission spectrum of barium.

How could this be used to show that the solution contains barium or any other elements?

Answer

The emission spectrum of barium could be used to show that the solution contains barium or any other elements by:

- (If the solution contains barium) the lines in the spectra line up / are in the same place / show the same pattern; [1 mark] *Allow each element has its own / unique spectrum*
- Extra lines show there are other elements in the solution / other elements show different lines; [1 mark]

[Total: 2 marks]

(2 marks)

(c) The student noticed that the lines produced in the spectrum did not produce the same level of light intensity.

Explain what information this gives about the elements in the sample?

Answer

The information this gives about the elements in the sample is:

- The intensity of light is a measure of how much of the element is present in the sample; [1 mark]
- So it is a measure of the element's concentration; [1 mark]

[Total: 2 marks]

- The light intensity is proportional to the number of ions that have been vaporised in the sample
- The concentration can be found by comparing it to the spectra of standard solutions of known concentrations

(2 marks)

(d) The student identified that iodide ions were present from the emission spectrum of the solution and confirmed their presence by adding dilute nitric acid and silver nitrate to the solution in question.

A yellow precipitate was formed.

Give the ionic equation, including state symbols, which shows the formation of the yellow precipitate.

Answer

The ionic equation which shows the formation of the white precipitate is:

$$Ag^{+}(aq) + I^{-}(aq) \rightarrow AgI(s)$$

- Correct formulae of reactants and products; [1 mark]
- All state symbols correct; [1 mark]

[Total: 2 marks]

- Make sure you learn the charges on key ions, silver is an ion that you are expected to know the charge of
- The silver and iodide ions are both in solutions so will be aqueous
- Silver iodide is the yellow precipitate formed which is insoluble in water and, therefore, forms a solid in solution

(2 marks)