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.
nitrate (NO_3^-) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulphate (SO_4^{2-}) [in solution]	acidify with dilute nitric acid, then add aqueous barium nitrate	white ppt.

TESTS FOR AQUEOUS CATIONS

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
ammonium (NH_4^+)	ammonia produced on warming	—
calcium (Ca^{2+})	white ppt., insoluble in excess	no ppt.
copper(II) (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
lead(II) (Pb^{2+})	white ppt., soluble in excess giving a colourless solution	white 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

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

TESTS FOR GASES

gas	test and result
ammonia (NH_3)	turns damp red litmus paper blue
carbon dioxide (CO_2)	given white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	"pops" with a lighted splint
oxygen (O_2)	relights a glowing splint
sulphur dioxide (SO_2)	turns aqueous potassium dichromate (VI) from orange to green

COLOURS OF SOME COMMON METAL HYDROXIDES

Calcium hydroxide	white
Copper(II) hydroxide	light blue
Iron(II) hydroxide	green
Iron(III) hydroxide	red-brown
Lead(II) hydroxide	white
Zinc hydroxide	white

NOTES ON QUALITATIVE ANALYSIS

In the practical examination, candidates are usually provided with unknown substance(s) and the necessary experimental procedures. They are expected to carry out tests according to the given procedures, record all observations and deduce the nature of the unknown substance(s).

The following are some notes that could be of great help to candidates when performing a qualitative experiment.

1. If candidates are given the following instruction:

   (a) "Carry out the following experiments and record all your observations and deductions of the unknown substance **W**."

   Such instruction implies that candidates are expected to identify the unknown with the results of the experiments. For example: **W** is copper(II) nitrate.

   (b) "You are not required to identify the unknown substance **W** but you must describe all that you observe, identify any gas evolved and state any conclusions you draw from the experiments."

   In this case, candidates are expected to state the action of the unknown substance **W** with other reagents or certain identifiable products produced by **W**. For example: **W** is an acid or alkali in nature or **W** is reducing or oxidizing in nature.

   (c) "You are required to identify the anion of the sodium salt and the metal of the oxide by carrying out tests of your own in addition to those described. Positive tests only are required."

   In this case, candidates are required to design and perform confirmatory tests to identify the substance given. The details of the tests should be clearly described.

2. Candidates are advised to record all observations immediately after performing a test. Recordings should be brief but complete. Phrases should be used instead of sentences for recording changes observed. Negative results should also be recorded as deduction may sometimes be drawn from them. Chemical formulae could be used instead of spelling out the chemical name in full.

3. "Observations" refer to changes that are seen by candidates during experiments. Some of the common visible changes include:

   (a) changes in colour,

   (b) formation of a precipitate,

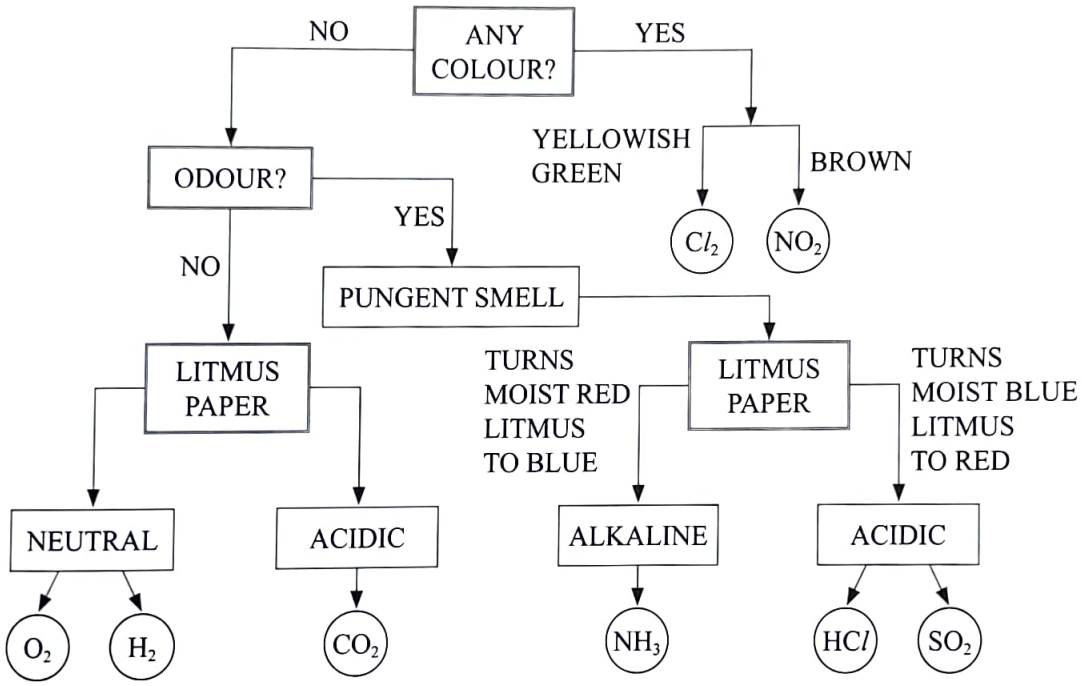
   (c) evolution of gases,

   (d) absorbing or giving out heat.

   Candidates should bear in mind that if there is no visible change observed after performing a test, the phrase "No visible reaction" should be recorded under the Observation Column rather than leaving it blank.

4. Gases that are produced due to the addition of reagents must not be recorded as observations. For example, the use of aqueous ammonia as reagent is always associated with evolution of ammonia gas. This is not a change, hence should not be regarded as an observation.

5. It will be easy to distinguish and identify gases if candidates learn in advance their colours, odours and effects on moist litmus paper. The flowchart below illustrates the basic approach for distinguishing and identifying gases.



6. Candidates should bear in mind the following when making a deduction:

   (a) A deduction must be specific. Statement, such as "**W** contains Cu++", should be written instead of using statement like "Copper or Cu++".

   (b) The identity of a gas should not be given as a deduction. Such information should be regarded as an observation. Instead, the identity of the substance that is responsible for the gas to give off should be regarded as part of the deductions.

   (c) The recording of a deduction should be made as soon as an observation is recorded for such deduction will serve to provide an immediate source of information for subsequent tests.

7. In experiments where conclusions about the identity or the nature of the unknowns need to be drawn, candidates may simply combine all deductions recorded during the experiment. For instance, if substance **W** was found containing Copper(II) ions from one test and sulphate(VI) ions from another, the conclusion may be made as: "**W** is copper(II) sulphate".

ANALYSIS TABLES

TABLE 1 COLOUR OF SUBSTANCES

Colour of Unknown Substance	Deduction
Black	Oxides of copper(II), iron(II) or manganese(VI), iodine crystals
Blue	copper(II) salt
Reddish Brown	iron(III) salt, copper metal
Green/light green	iron(II) salt, copper(II) salt
Grey	Powder form of metals like zinc, iron or aluminium
White	Absence of coloured salts like iron(II), iron(III), copper(II) and other transition elements
Colourless solution	Dilute acids or alkalis or hydrogen peroxide
Purple	potassium manganate(VII)
Orange	potassium dichromate(VI)
Pink	cobalt(II) salts
Yellow	iron(III) chloride solution

TABLE 2 SOLUBILITY OF SALTS

Type of Salt	Solubility
Carbonate	All are insoluble except those of Na^+, K^+ and NH_4^+
Chloride	All are soluble except $PbCl_2$ and $AgCl$
Iodide	All are soluble except PbI_2 and AgI
Nitrate	All are soluble
Sulphate	All are soluble except $PbSO_4$, $BaSO_4$ and $CaSO_4$
Hydroxide	All are insoluble except those of Na^+, K^+ and NH_4^+
Sodium, Potassium, Ammonium	All are soluble

TABLE 3 TEST FOR GASES

No.	GAS	COLOUR	ODOUR	LITMUS TEST	CONFIRMATORY TEST
1.	Oxygen (O_2)	Colourless	Odourless	Neutral	Glowing splinter glows brighter or rekindled
2.	Hydrogen (H_2)	Colourless	Odourless	Neutral	'Pop' sound when lighted splinter applied
3.	Carbon dioxide (CO_2)	Colourless	Odourless	Blue to red	Lime water turned chalky
4.	Ammonia (NH_3)	Colourless	Pungent smell of ammonia	Red to blue	Dense white fumes when exposed to concentrated hydrochloric acid
5.	Chlorine (Cl_2)	Greenish-yellow	Choking smell	Blue to red and finally bleached	Potassium iodide solution turned brownish
6.	Nitrogen dioxide (NO_2)	Brown (often accompanied by O_2)	Choking smell	Blue to red	—
7.	Water vapour (H_2O)	Colourless	Odourless	Neutral	Blue cobalt chloride paper turned pink

TABLE 4 HEATING OF AN UNKNOWN SUBSTANCE

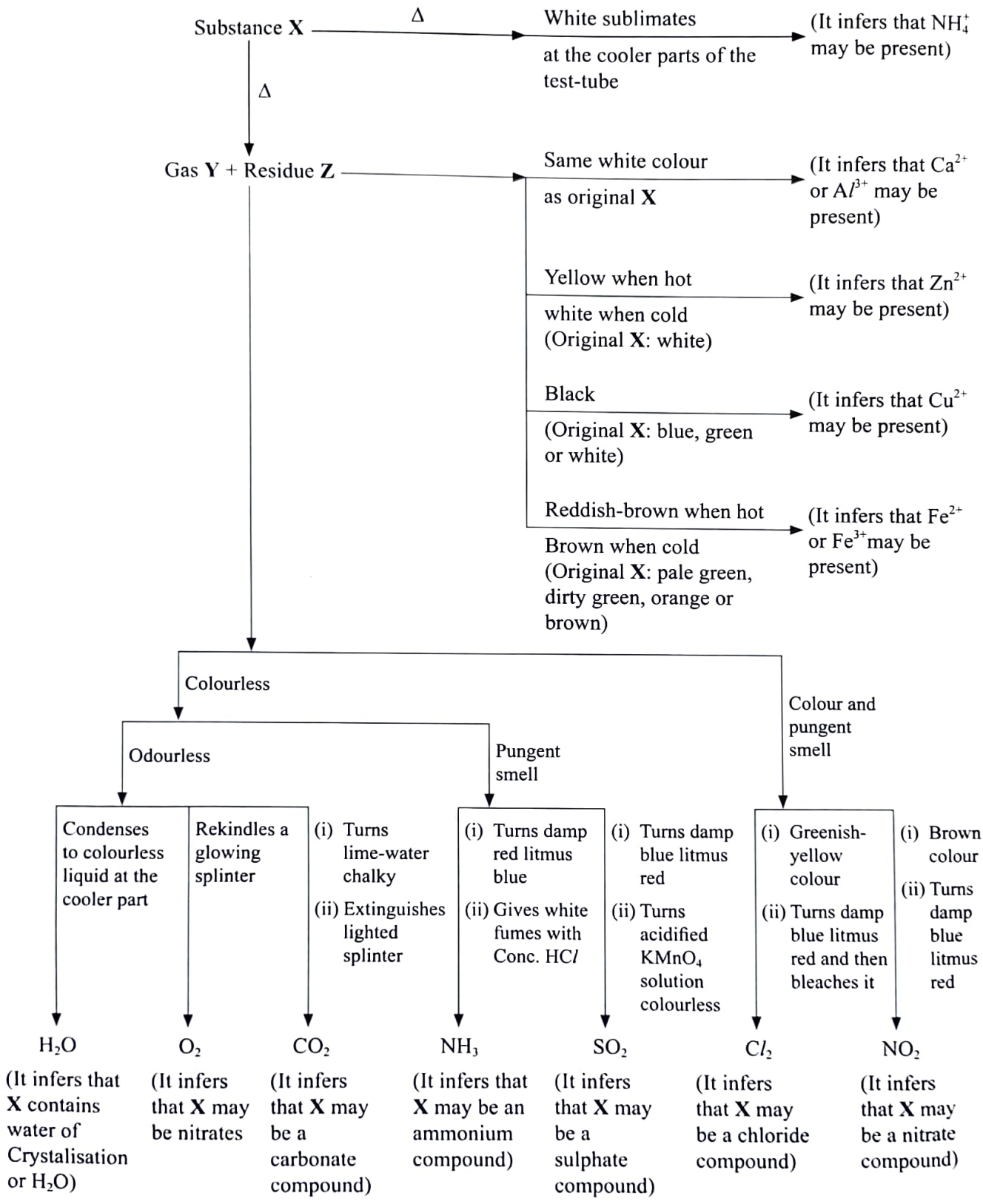


TABLE 5 TEST FOR CATIONS

	REAGENTS	SODIUM HYDROXIDE SOLUTION, NaOH		AQUEOUS AMMONIA	
	CATION	Add a little	Add excess	Add a little	Add excess
1.	Calcium ion Ca^{2+}	White ppt.	ppt. insoluble	No ppt.	No ppt.
2.	Zinc ion Zn^{2+}	White ppt.	ppt. soluble	White ppt.	ppt. soluble
3.	Aluminium ion Al^{3+}	White ppt.	ppt. soluble	White ppt.	ppt. insoluble
4.	Iron(II) ion Fe^{2+}	Green ppt.	ppt. insoluble	Green ppt.	ppt. insoluble
5.	Iron(III) ion Fe^{3+}	Reddish-brown ppt.	ppt. insoluble	Reddish-brown ppt.	ppt. insoluble
6.	Copper(II) ion Cu^{2+}	Blue ppt.	ppt. insoluble	Blue ppt.	ppt. soluble to form dark blue solution
7.	Ammonium ion NH_4^+	No ppt.	No ppt.	No ppt.	No ppt.

	Reaction of cations with NaOH solution	Reaction of cations with NH_4OH solution
1.	$Ca^{2+} + 2OH^- \rightarrow Ca(OH)_2$ white ppt.	$Ca^{2+} + 2OH^- \rightarrow$ No ppt.
2.	$Zn^{2+} + 2OH^- \rightarrow Zn(OH)_2$ white ppt. $Zn(OH)_2(s) + 2OH^-(excess) \rightarrow Zn(OH)_4^{2-}(aq)$ zincate ion	$Zn^{2+} + 2OH^- \rightarrow Zn(OH)_2$ white ppt. $Zn(OH)_2(s) + 4NH_3 \rightarrow Zn(NH_3)_4^{2+}(aq) + 2OH^-$ Tetra-amine zinc ions
3.	$Al^{3+} + 3OH^- \rightarrow Al(OH)_3$ white ppt. $Al(OH)_3(s) + OH^-$ (excess $\rightarrow Al(OH)_4^{3-}$ (aq) aluminate ion	$Al^{3+} + 3OH^- \rightarrow Al(OH)_3$ white ppt.
4.	$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ green ppt.	$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ green ppt.
5.	$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3$ reddish brown ppt.	$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3$ reddish brown ppt.
6.	$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$ blue ppt.	$Cu(OH)_2 + 4NH_3 \rightarrow Cu(NH_3)_4^{2+}(aq) + 2OH^-$ Tetra-amine copper(II) ions

TABLE 6 A QUICK IDENTIFICATION OF CATIONS

The table will distinguish between calcium, zinc, iron, lead and copper in solutions.

TEST	POSSIBLE OBSERVATIONS	CONCLUSIONS
1. Excess sodium hydroxide solution is added dropwise  Solution of unknown salt	White precipitate soluble in excess	Al^{3+} or Zn^{2+} present
	White precipitate insoluble in excess	Ca^{2+} present
	Dirty green or brown precipitate	Green ppt. is Fe^{2+} Brown ppt. is Fe^{3+}
	Light blue precipitate	Cu^{2+} present
	No precipitate but ammonia gas evolved on warming	NH_4^+ present
	No precipitate	Should suspect the presence of Na^+ or K^+
2. Excess aqueous ammonia is added dropwise  Solution of unknown salt	White precipitate soluble in excess	Zn^{2+} present
	White precipitate insoluble in excess	Al^{3+} present
	Dirty green or brown precipitate	Green ppt. is Fe^{2+} Brown ppt. is Fe^{3+}
	Light blue precipitate soluble in excess to form a deep blue solution	Cu^{2+} present
	No precipitate	Should suspect the presence of Ca^{2+}, Na^+ or K^+

TABLE 7 TEST FOR ANIONS

Anions	+ dilute HCl or dilute HNO_3	+ $Ba(NO_3)_2$/dilute HNO^3	+ $AgNO_3$/dilute HNO_3	+ Conc. H_2SO_4
CO_3^{2-}	Efferverscence occurred. Gas evolved turned lime water chalky. The gas is CO_2.	White ppt. Soluble in acid. Gas evolved turned lime water chalky. The gas is CO_2.	White ppt., turning pale yellow. Soluble in acid. Gas evolved turned lime water chalky. The gas is CO_2.	Efferverscence occurred. Gas evolved turned lime water chalky. The gas is CO_2.
SO_3^{2-}	Efferverscence occurred. Gas evolved decolourised acidified potassium manganate(VII). The gas is SO_2.	White ppt. Soluble in acid. Gas evolved decolourised acidified potassium manganate(VII). The gas is SO_2.	White ppt. Soluble in acid. Gas evolved decolourised acidified potassium manganate(VII). The gas is SO_2.	Efferverscence occurred. Gas evolved decolourised acidified potassium manganate(VII). The gas is SO_2.
SO_4^{2-}	No visible reaction.	White ppt. Insoluble in dilute HNO_3. (Confirmatory Test)	White ppt. Insoluble in acid if concentrated solution is used.	No visible reaction.
Cl^-	No visible reaction.	No visible reaction.	White ppt. Insoluble in dilute HNO_3 but soluble in aqueous NH_3. (Confimatorry Test for Cl^-.)	Gas evolved turned blue litmus red. White fumes produced with aqueous NH_3 solution. The gas is HCl.
NO_3^-	White ppt. No gas evolved. * No visible reaction.	No visible reaction.	No visible reaction.	Brown gas evolved on heating. The gas is NO_2.

Equations:

1. $CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$

2. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
   $AgCl(s) + 2NH_3(aq) \rightarrow Ag(NH_3)_2^+(aq) + Cl^-(aq)$

3. (a) $Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$
   (b) $Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$

4. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

TABLE 8 A QUICK IDENTIFICATION OF ANIONS

This table will detect carbonate, sulphate, chloride and nitrate. Note that a precipitate is a solid formed when two solutions are mixed.

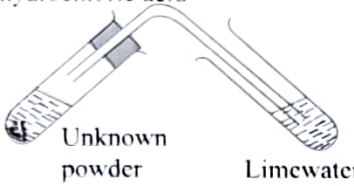
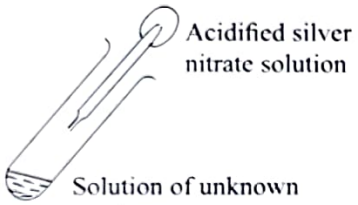
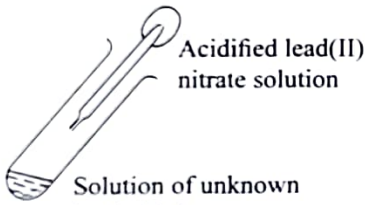
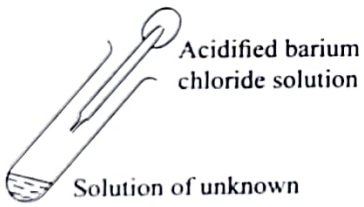
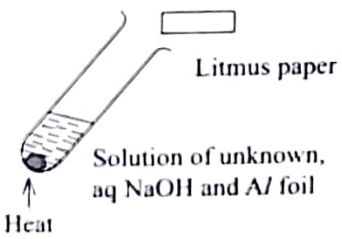
TEST (if Test 1 is positive, leave out Tests 2, 3 and 4)	POSSIBLE OBSERVATIONS	CONCLUSIONS
1. Dilute hydrochloric acid 	Limewater turns chalky, proving that carbon dioxide has been given off.	Carbonate present
	No gas given off	Carbonate absent
2. 	White precipitate of silver chloride	Chloride present
	No change	Chloride absent
3. 	Yellow precipitate of lead (II) iodide	Iodide present
	No change	Iodide absent
4. 	White precipitate of barium sulphate	Sulphate present
	No change	Sulphate absent
5. 	Pungent gas evolved turns red litmus blue	Nitrate present
	No pungent gas evolved	Nitrate absent

TABLE 9 TESTS FOR ACIDS AND ALKALIS

To an unknown liquid, add one of the following indicators and check the colour obtained.

INDICATOR	COLOUR IN ACIDIC SOLUTION	COLOUR IN ALKALINE SOLUTION
Litmus	Red	Blue
Phenolphthalein	Colourless	Pink
Methyl orange	Red	Yellow

TABLE 10 TESTS FOR STRENGTH OF ACIDS AND ALKALIS — pH OF SOLUTIONS

pH is a number scale used to describe how acidic or alkaline a solution is. The pH of a solution is usually measured by the use of the Universal indicator which shows a different colour in solution with different pH.

pH VALUE	COLOUR	ACIDIC/ALKALINE
1	Red	Strong acid
2	Red	
3	Orange	↓ Decrease in acidity
4	Orange	
5	Yellow	
6	Yellow	Weak acid
7	Yellow-green	Neutral
8	Blue-green	Weak alkali
9	Blue-green	
10	Blue-green	↓ Increase in alkalinity
11	Blue	
12	Blue	
13	Violet	
14	Violet	Strong alkali

TABLE 11 TEST FOR OXIDISING AGENTS

To test for an oxidising agent, a reducing agent is added to it.

OXIDISING AGENT	OBSERVATION WHEN A REDUCING AGENT IS ADDED
Acidified potassium manganate(VII) solution	Turns from purple to colourless
Acidified potassium dichromate(VI) solution	Turns from orange to green
Fresh iron(III) chloride solution	Turns from reddish-brown to green
Iodine solution	Turns from brown to colourless

TABLE 12 TEST FOR REDUCING AGENTS

To test for a reducing agent, an oxidising agent is added to it.

REDUCING AGENT	OBSERVATION WHEN AN OXIDISING AGENT IS ADDED
Acidified potassium iodide solution	Turns from colourless to brown. (Iodine formed is confirmed by adding starch which turns dark blue.)
Acidified iron(II) sulphate solution	Turns from green to yellow. (Iron(III) ion formed is confirmed by adding NaOH which forms a reddish-brown ppt.)
Concentrated hydrochloric acid	Chlorine gas evolved. (Gas formed is confirmed by moist blue litmus paper which is bleached.)