Mastering Chemistry

Book 8

Topic 15 Analytical Chemistry

Content

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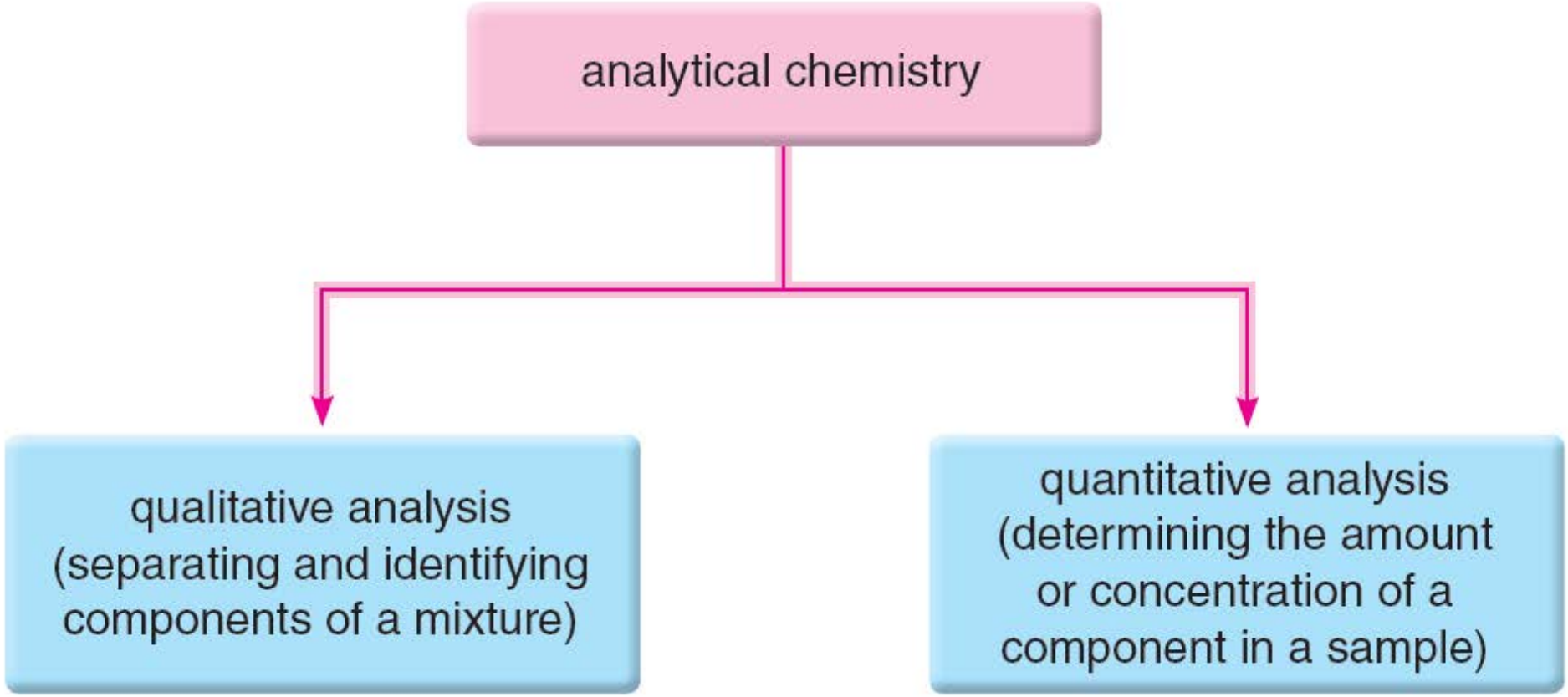
Content

51.1 Introduction to analytical chemistry (p.2)

- **Analytical chemistry (分析化學)** is a branch of chemistry which deals with the analysis of chemical species of all sorts. It is concerned with the separation, identification and determination of the relative amounts of the components making up a sample.
- Much of your daily life depends on analytical chemistry. For example, accurate quality control analysis ensures the qualities of the food you eat, the medicine you use, the water you drink and the air you breathe.

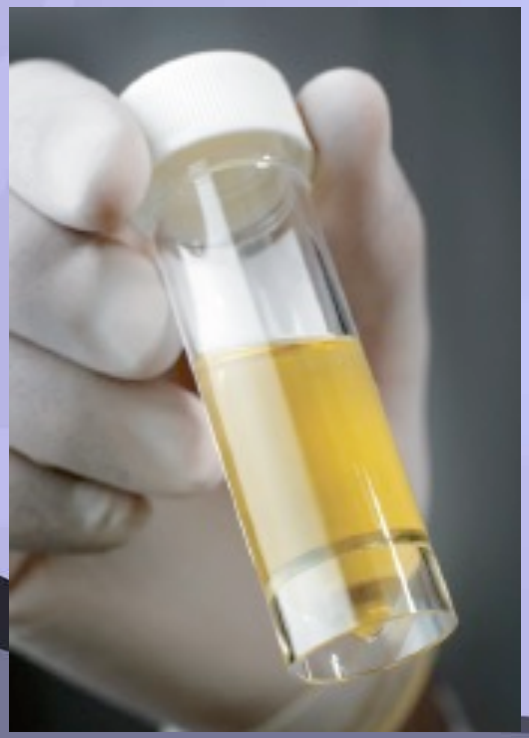
51.1 Introduction to analytical chemistry (p.2)

- Analytical chemistry can be split into two main types — qualitative and quantitative.



51.1 Introduction to analytical chemistry (p.2)

- **Qualitative analysis (定性分析)** refers to an analyse in which components of a mixture are separated and identified, examples of which include identifying the products of a chemical reaction, or screening an athlete's urine for the presence of a performance-enhancing drug.



Qualitative analysis is needed in screening of athlete's urine for the presence of performance-enhancing drug

51.1 Introduction to analytical chemistry (p.2)

- **Quantitative analysis (定量分析)** refers to an analyse in which the amount or concentration of a certain component in a sample is determined, examples of which include measuring the concentration of glucose in blood, or measuring the concentration of carbon monoxide in air.
- Usually qualitative analysis is carried out before quantitative analysis.

Quantitative analysis is needed in measuring the concentration of glucose in blood

51.2 The tests for gases (p.4)

- Several of the tests for cations and anions involve detecting gases produced by the test reactions.

Gas or vapour	Colour and smell	Test	Test result and equation (if appropriate)
Ammonia	• colourless • choking and pungent smell	Insert a piece of moist red litmus paper into the gas.	The moist red litmus paper turns blue.
Carbon dioxide	• colourless • odourless	Pass the gas through limewater.	The limewater turns milky (Fig. 51.4). $Ca(OH)_2(aq) + CO_2(g) \longrightarrow CaCO_3(s) + H_2O(l)$
Chlorine	• pale green • choking smell	Insert a piece of moist blue litmus paper into the gas.	The moist blue litmus paper is bleached (the litmus paper turns red first) (Fig. 51.5). $Cl_2(g) + H_2O(l) \rightleftharpoons HCl(aq) + HOCl(aq)$

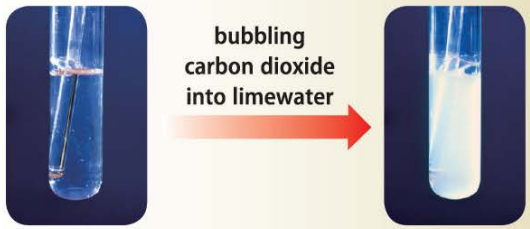


Fig. 51.4 *Testing carbon dioxide using limewater*

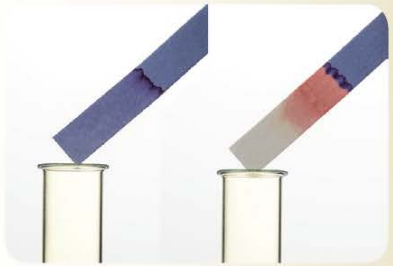


Fig. 51.5 *Testing chlorine using moist blue litmus paper*

51.2 The tests for gases (p.4)

Gas or vapour	Colour and smell	Test	Test result and equation (if appropriate)
Sulphur dioxide	• colourless • choking acidic smell	Insert a piece of filter paper soaked with acidified potassium dichromate solution into the gas.	The filter paper turns from orange to green (Fig. 51.6). $Cr_2O_7^{2-}(aq) + 2H^+(aq) + 3SO_2(g) \longrightarrow 2Cr^{3+}(aq) + H_2O(l) + 3SO_4^{2-}(aq)$  ***Fig. 51.6*** *Testing sulphur dioxide using filter paper soaked with acidified $K_2Cr_2O_7(aq)$*
Hydrogen chloride	• colourless • choking smell • acidic steamy fumes in moist air	Dip a glass rod in aqueous ammonia and insert it into the gas.	Dense white fumes are formed (Fig. 51.7). $NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$  ***Fig. 51.7*** *Testing hydrogen chloride using $NH_3(aq)$*
Water vapour	• colourless • odourless	Insert a piece of blue cobalt(II) chloride paper into the vapour.	The blue cobalt(II) chloride paper turns pink.
Hydrogen	• colourless • odourless	Insert a burning splint into the gas.	The burning splint gives a 'pop' sound. $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$
Oxygen	• colourless • odourless	Insert a glowing splint into the gas.	The glowing splint relights.

51.2 The tests for gases (p.4)

Practice 51.1

Suggest a chemical test to detect each of the following gases. Write an equation for the reaction involved.

a) Hydrogen chloride gas

Dip a glass rod in aqueous ammonia and insert it into hydrogen chloride gas. / Place hydrogen chloride gas near concentrated aqueous ammonia.
Dense white fumes are observed.

$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$

b) Sulphur dioxide gas

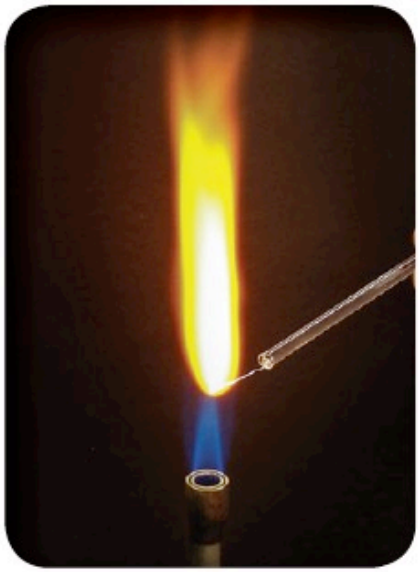
Insert a piece of filter paper soaked with acidified potassium dichromate solution into sulphur dioxide gas.
The filter paper turns from orange to green.

$Cr_2O_7^{2-}(aq) + 2H^+(aq) + 3SO_2(g) \longrightarrow 2Cr^{3+}(aq) + H_2O(l) + 3SO_4^{2-}(aq)$

51.3 Identifying the cation in a sample (p.6)

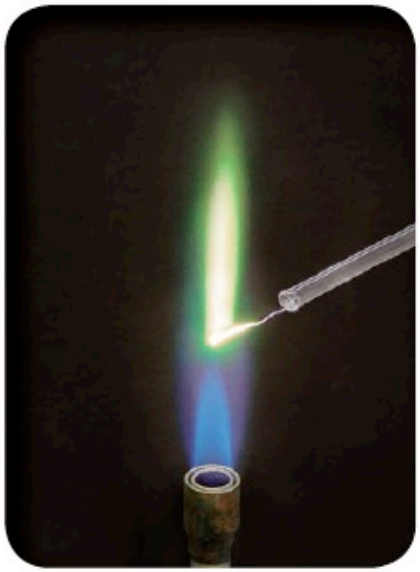
Flame tests

lilac



golden yellow

brick-red



bluish green

Flame colours of some cations

51.3 Identifying the cation in a sample (p.6)

- You can use flame colours to identify particular cations present in samples.

Colour of flame	Cation likely to be present
Lilac	potassium ion
Golden yellow	sodium ion
Brick-red	calcium ion
Bluish green	copper(II) ion

- Method
  - Moisten a clean nichrome wire by dipping it into concentrated hydrochloric acid. Then dip it into the sample under test.
  - Hold the wire in the hottest part of a non-luminous flame, and observe the colour of the flame.

51.3 Identifying the cation in a sample (p.6)

Precipitation reactions for cations

- A hydroxides, except those of Group I metals and ammonium, are insouble in water and often have characteristic appearances. Some dissolve in excess aqueous solution of sodium hydroxide and some dissolve in excess aqueous ammonia.
- The addition of dilute aqueous solution of sodium hydroxide or dilute aqueous ammonia to an aqueous solution of a sample under test gives valuable information about the cations present.

51.3 Identifying the cation in a sample (p.6)

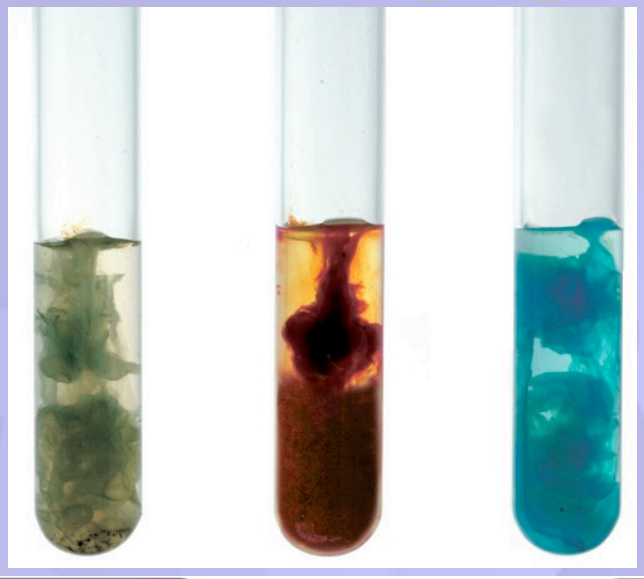
- Method
  - Dissolve a spatula measure of the sample under test in water.
  - Add a few drops of dilute aqueous solution of sodium hydroxide or dilute aqueous ammonia. Notice the colour of any precipitate formed.
  - Add dilute aqueous solution of sodium hydroxide or dilute aqueous ammonia until in excess. Notice the solubility of the precipitate and the colour of the resulting solution if the precipitate dissolves.

51.3 Identifying the cation in a sample (p.6)

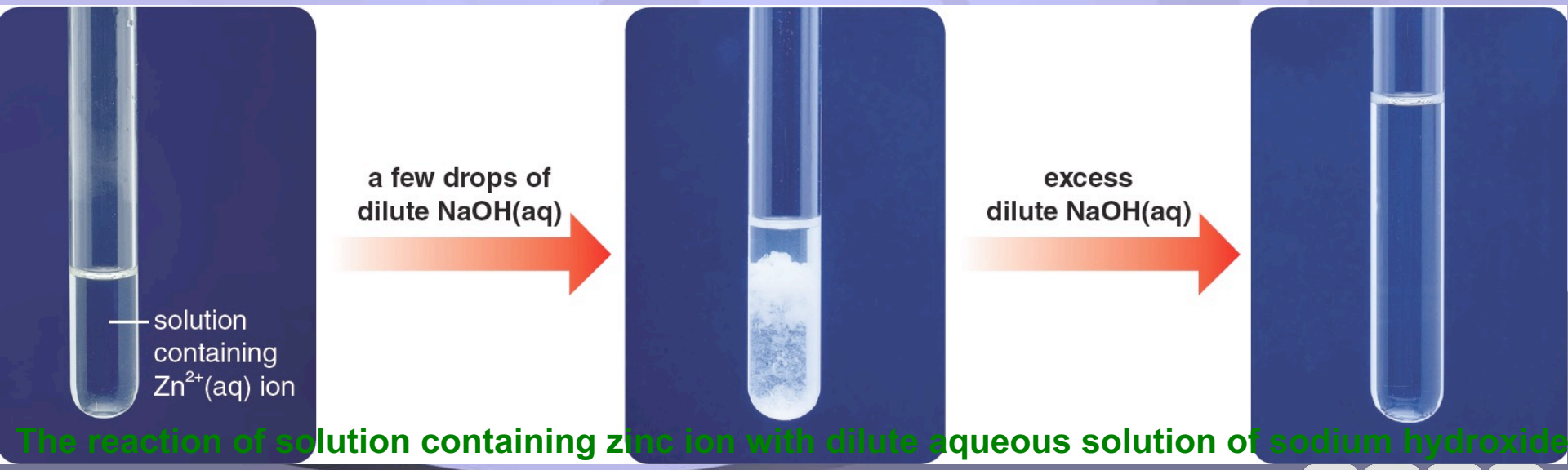
- The observations when dilute aqueous solution of sodium hydroxide is added to solutions containing some cations.

Cation		On addition of a few drops of dilute NaOH(aq)	On addition of excess dilute NaOH(aq)
Group II	Mg^{2+}	white precipitate	precipitate is insoluble
	Ca^{2+}	white precipitate	precipitate is insoluble
Groups III and IV	Al^{3+}	white precipitate	precipitate is soluble (forming a colourless solution)
	Pb^{2+}	white precipitate	precipitate is soluble (forming a colourless solution)
Transition metals	Fe^{2+}	green precipitate	precipitate is insoluble
	Fe^{3+}	reddish brown precipitate	precipitate is insoluble
	Cu^{2+}	blue precipitate	precipitate is insoluble
	Zn^{2+}	white precipitate	precipitate is soluble (forming a colourless solution)

51.3 Identifying the cation in a sample (p.6)



The precipitates formed by $Fe^{2+}(aq)$, $Fe^{3+}(aq)$ and $Cu^{2+}(aq)$ ions with dilute aqueous solution of sodium hydroxide (left to right)



The reaction of solution containing zinc ion with dilute aqueous solution of sodium hydroxide

51.3 Identifying the cation in a sample (p.6)

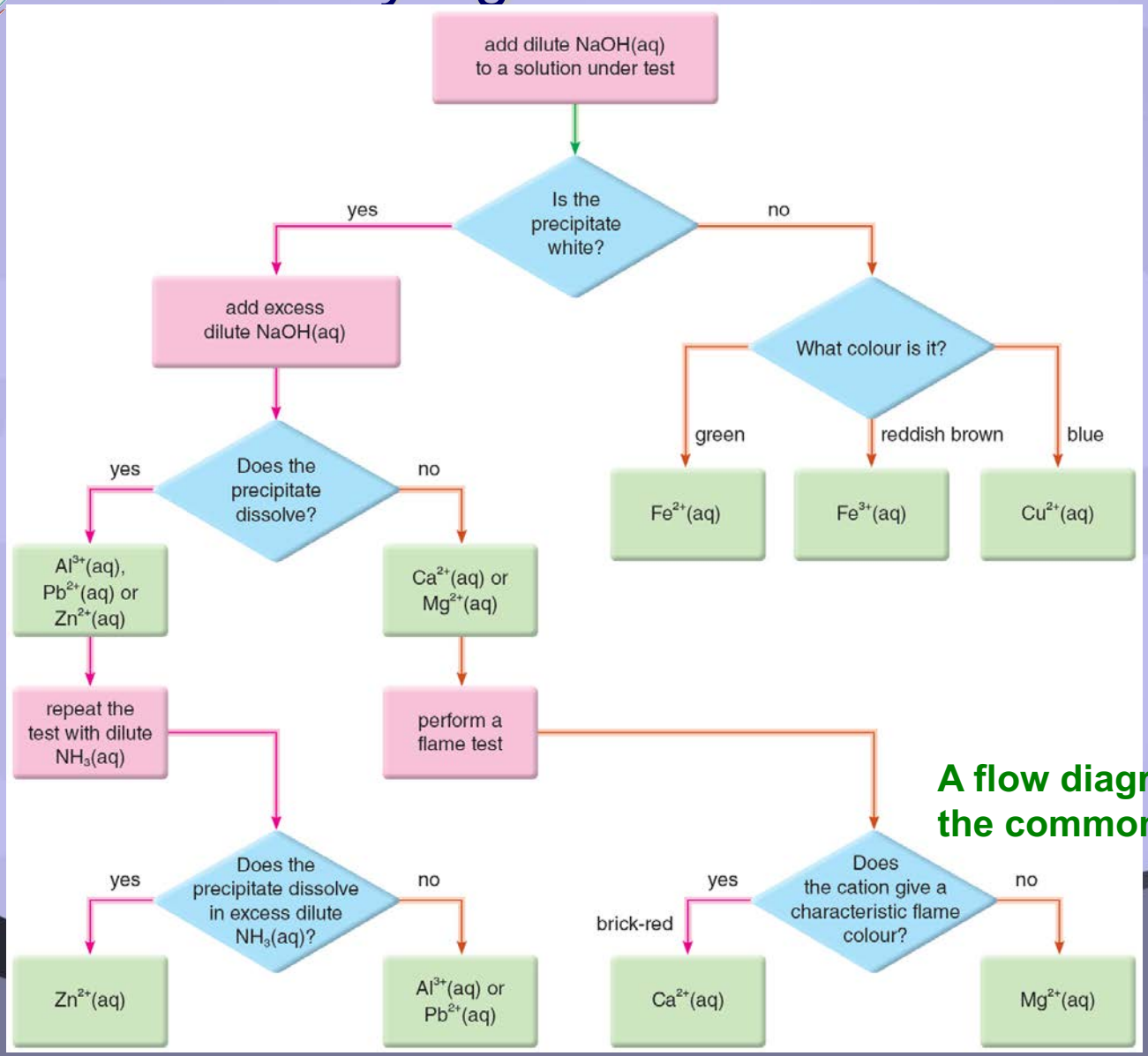
- The observations when dilute aqueous ammonia is added to solutions containing some cations.

Cation		On addition of a few drops of dilute $NH_3(aq)$	On addition of excess dilute $NH_3(aq)$
Group II	Mg^{2+}	white precipitate	precipitate is insoluble
	Ca^{2+}	no precipitate	—
Groups III and IV	Al^{3+}	white precipitate	precipitate is insoluble
	Pb^{2+}	white precipitate	precipitate is insoluble
Transition metals	Fe^{2+}	green precipitate	precipitate is insoluble
	Fe^{3+}	reddish brown precipitate	precipitate is insoluble
	Cu^{2+}	pale blue precipitate	precipitate is soluble (forming a deep blue solution)
	Zn^{2+}	white precipitate	precipitate is soluble (forming a colourless solution)

51.3 Identifying the cation in a sample (p.6)

The reaction of solution containing copper(II) ion with dilute aqueous ammonia

51.3 Identifying the cation in a sample (p.6)



A flow diagram used to identify the common cations

51.3 Identifying the cation in a sample (p.6)

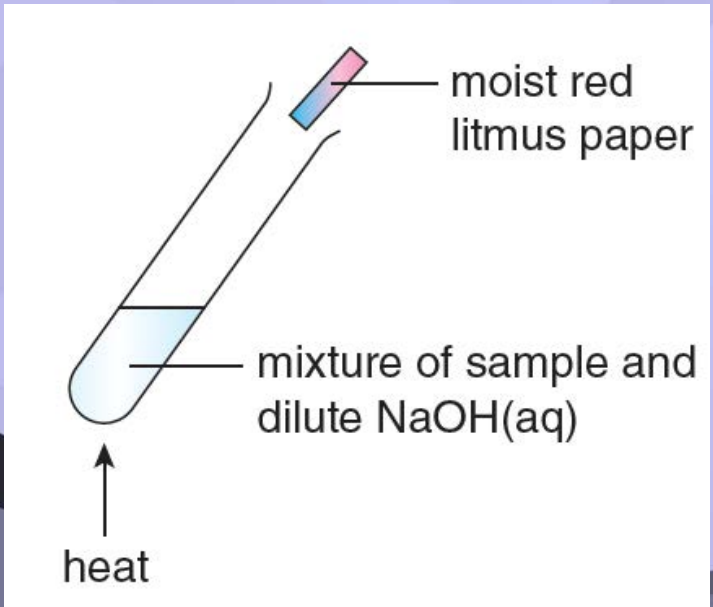
Test for ammonium ion

- Ammonium ion reacts with dilute aqueous solution of sodium hydroxide to give ammonia gas and water. For example, warming an aqueous solution of ammonium sulphate with dilute aqueous solution of sodium hydroxide gives ammonia gas.

$$NH_4^+(aq) + OH^-(aq) \xrightarrow{\text{heat}} NH_3(g) + H_2O(l)$$

51.3 Identifying the cation in a sample (p.6)

- Method
  - Add dilute aqueous solution of sodium hydroxide to the sample in either solid form or in solution.
  - Warm the mixture gently.
  - Insert a piece of moist red litmus paper into any gas evolved.
  - Ammonium ion is present in the sample if the paper turns from red to blue.



A sample containing ammonium ion gives a gas that turns moist red litmus paper blue when warmed with dilute NaOH(aq)

51.3 Identifying the cation in a sample (p.6)

Q (Example 51.1)

State the expected observation in each of the following experiments, and account for the observation with the aid of ionic equation(s).

a) Adding NaOH(aq) dropwise to $Pb(NO_3)_2(aq)$ until in excess
b) Adding excess $H_2SO_4(aq)$ to $K_2CrO_4(aq)$, and then excess $FeSO_4(aq)$ to the resulting mixture
c) Warming a mixture of $(NH4)_2SO_4(aq)$ and $CuSO_4(aq)$ with excess NaOH(aq)

51.3 Identifying the cation in a sample (p.6)

A

a) A white precipitate forms.
The precipitate dissolves in excess NaOH(aq) to give a colourless solution.

$Pb^{2+}(aq) + 2OH^-(aq) \longrightarrow Pb(OH)_2(s)$

$Pb(OH)_2(s) + 2OH^-(aq) \longrightarrow [Pb(OH)_4]^{2-}(aq)$

b) Yellow $K_2CrO_4(aq)$ turns orange upon the addition of $H_2SO_4(aq)$.

$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$

yellow orange

c) A gas that turns moist red litmus paper blue is evolved.

$NH_4^+(aq) + OH^-(aq) \longrightarrow NH_3(g) + H_2O(l)$

A blue precipitate forms.

$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$

51.3 Identifying the cation in a sample (p.6)

Practice 51.2

Alums are salts. They have been used since ancient times in dyeing and making medicine. They still have many uses today.

The ions present in three alums are listed in the table below.

Name	Ions present		
Ammonium alum	NH_4^+	Al^{3+}	SO_4^{2-}
Potassium alum	K^+	Al^{3+}	SO_4^{2-}
Sodium alum	Na^+	Al^{3+}	SO_4^{2-}

a) These alums contain aluminium ion.
Describe how an aqueous solution of sodium hydroxide can be used to show this.

Add an aqueous solution of sodium hydroxide to an aqueous solution containing aluminium ions until in excess.

A white precipitate forms. The precipitate dissolves in excess alkali to give a colourless solution.

Identifying the cation in an unknown solid sample *Ref.*

51.3 Identifying the cation in a sample (p.6)

Practice 51.2 (continued)

b) Describe and give the result of a chemical test to show that ammonium alum contains ammonium ion.

Warm the ammonium alum with dilute aqueous solution of sodium hydroxide.

A gas that turns moist red litmus paper blue is evolved.

c) Flame tests can be used to distinguish these three alums.

i) Describe how you would carry out a flame test on an alum.

ii) Explain how these three alums can be distinguished from the results of flame tests.

i) • Moisture a clean nichrome wire by dipping it into concentrated hydrochloric acid. Then dip it into the sample under test.

• Hold the wire in the hottest part of a non-luminous flame, and observe the colour of the flame.

ii) • Golden yellow flame — sodium alum

• Lilac flame — potassium alum

• No characteristic flame colour — ammonium alum

51.4 Identifying the anion in a sample (p.13)

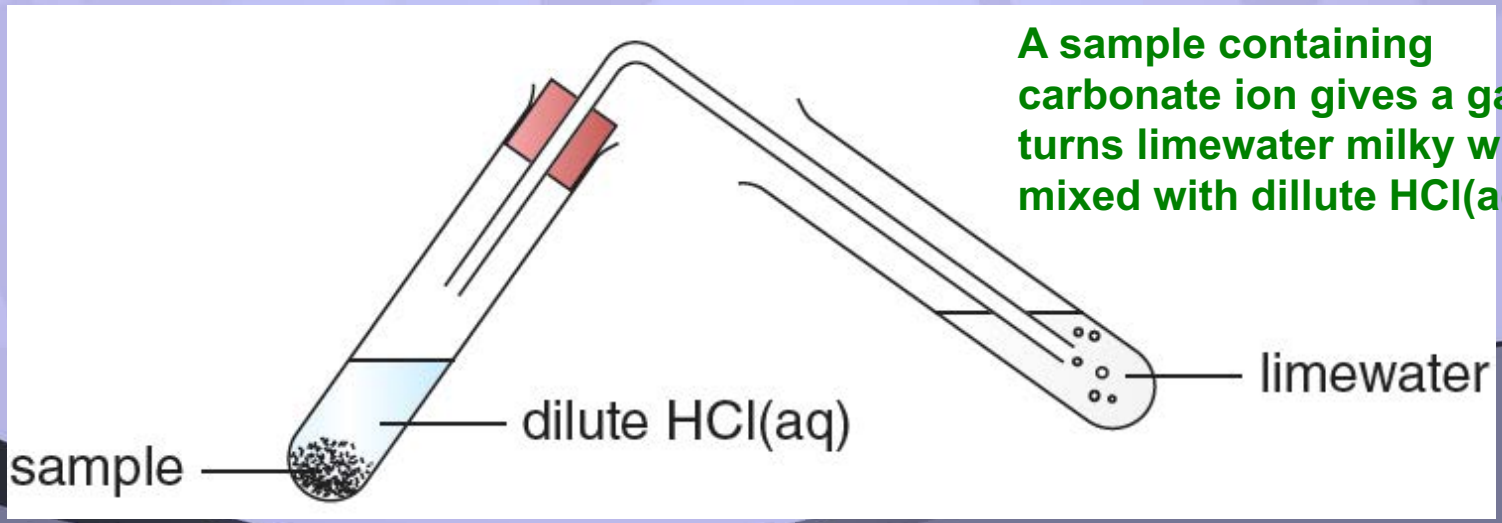
Carbonate ion

- Carbonate ion reacts with dilute hydrochloric acid to give carbon dioxide gas.
- For example, an aqueous solution of sodium carbonate reacts with dilute hydrochloric acid according to the ionic equation below.

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

51.4 Identifying the anion in a sample (p.13)

- Method
  - Add dilute hydrochloric acid to the sample in either solid form or in solution.
  - Collect any bubbles of gas and pass them through limewater.
  - Carbonate ion is present in the sample if the limewater turns milky.



A sample containing carbonate ion gives a gas that turns limewater milky when mixed with dillute HCl(aq)

51.4 Identifying the anion in a sample (p.13)

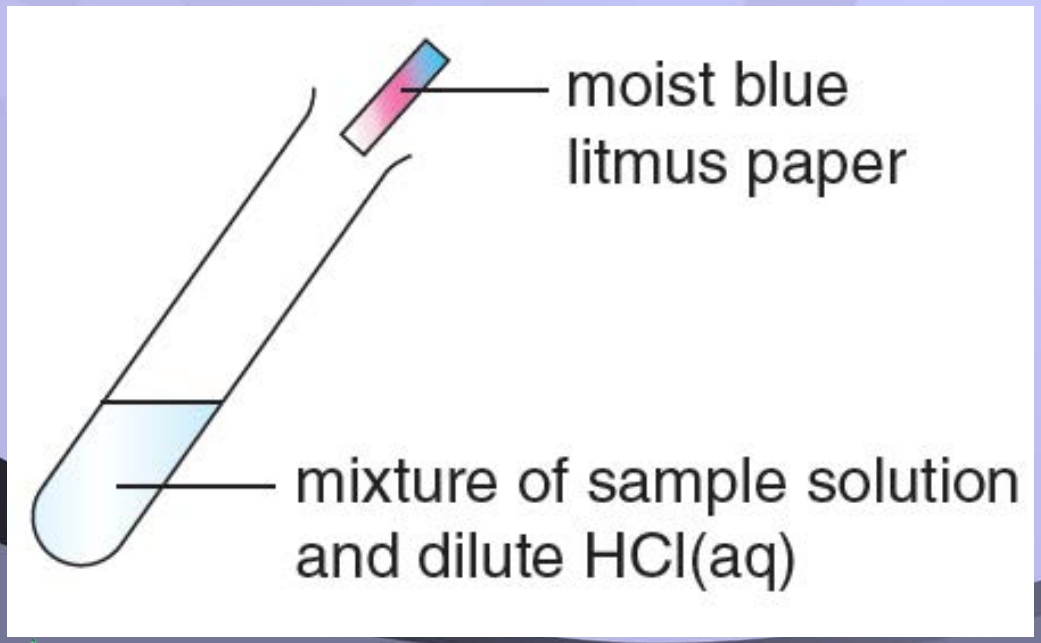
Hypochlorite ion

- Hypochlorite ion reacts with dilute hydrochloric acid to give chlorine gas.
- For example, an aqueous solution of sodium hypochlorite reacts with dilute hydrochloric acid according to the ionic equation below.

$$OCl^-(aq) + 2H^+(aq) + Cl^-(aq) \longrightarrow Cl_2(g) + H_2O(l)$$

51.4 Identifying the anion in a sample (p.13)

- Method
  - Add dilute hydrochloric acid to the sample solution.
  - Insert a piece of moist blue litmus paper into any gas evolved.
  - Hypochlorite ion is present in the sample solution if the litmus paper is bleached.



A sample containing hypochlorite ion gives a gas that bleaches moist blue litmus paper when mixed with dilute HCl(aq)

51.4 Identifying the anion in a sample (p.13)

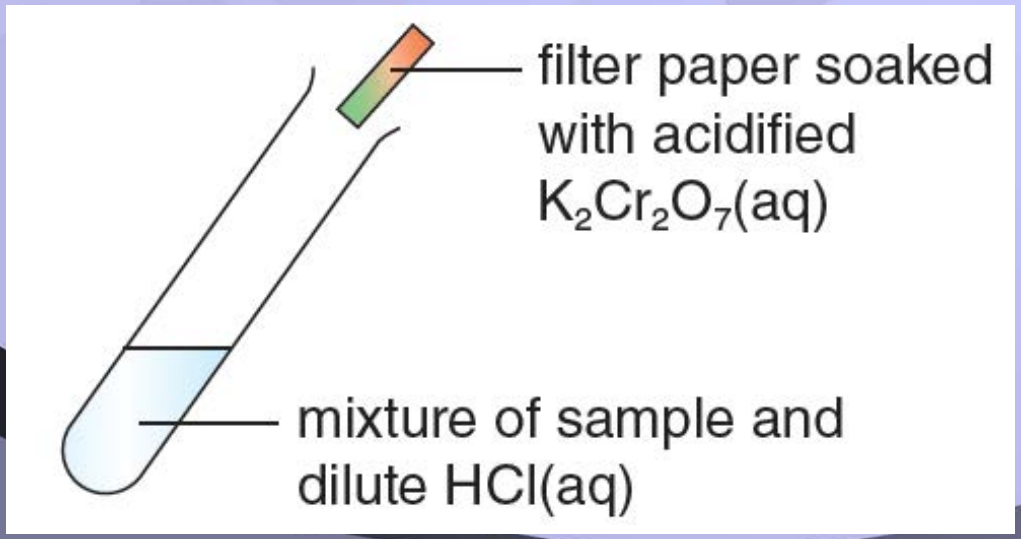
Sulphite ion

- Sulphite ion reacts with dilute hydrochloric acid to give sulphur dioxide gas.
- For example, an aqueous solution of sodium sulphite reacts with dilute hydrochloric acid according to the ionic equation below.

$$SO_3^{2-}(aq) + 2H^+(aq) \longrightarrow SO_2(g) + H_2O(l)$$

51.4 Identifying the anion in a sample (p.13)

- Method
  - Add dilute hydrochloric acid to the sample in either solid form or in solution.
  - Insert a piece of filter paper soaked with acidified aqueous solution of potassium dichromate into any gas evolved.
  - Sulphite ion is present in the sample if the paper changes from orange to green.



A sample containing sulphite ion gives a gas that turns filter paper soaked with acidified potassium dichromate solution from orange to green when mixed with dilute HCl(aq)

51.4 Identifying the anion in a sample (p.13)

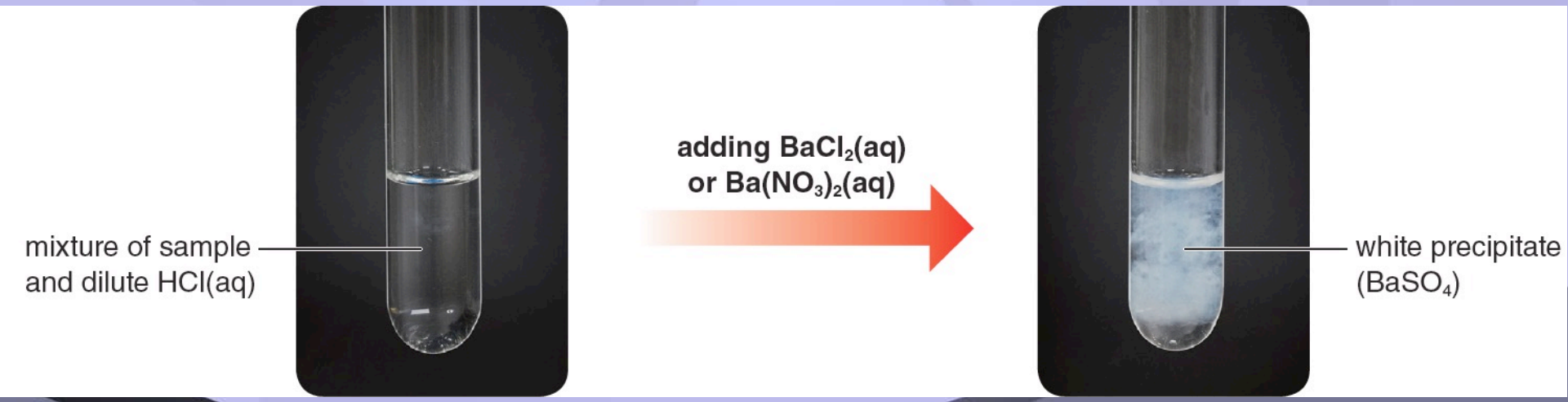
Sulphate ion

- An aqueous solution containing sulphate ion gives a white precipitate with an aqueous solution of barium chloride or barium nitrate.

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$$

51.4 Identifying the anion in a sample (p.13)

- Method
  - Add dilute hydrochloric acid to the sample in either solid form or in solution until the solution obtained is just acidic (test with litmus paper).
  - Add an aqueous solution of barium chloride or barium nitrate.
  - Sulphate ion is present in the sample if a white precipitate forms.



An acidic solution containing sulphate ion gives a white precipitate when mixed with an aqueous solution of barium chloride or barium nitrate

51.4 Identifying the anion in a sample (p.13)

Halide ions

- Silver chloride, silver bromide and silver iodide are insoluble in water. Thus, the presence of chloride, bromide and iodide ions in a solution can be detected by the addition of an aqueous solution of silver nitrate, $AgNO_3(aq)$.

$$Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$$

white precipitate

$$Ag^+(aq) + Br^-(aq) \longrightarrow AgBr(s)$$

creamy (pale yellow) precipitate

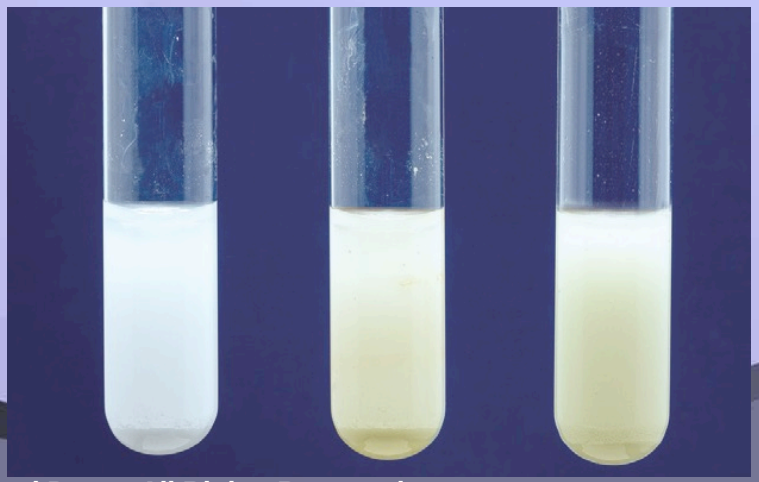
$$Ag^+(aq) + I^-(aq) \longrightarrow AgI(s)$$

yellow precipitate

51.4 Identifying the anion in a sample (p.13)

- Method

  Add dilute nitric acid to the sample in either solid form or in solution until the solution is just acidic (test with litmus paper).
  - Add an aqueous solution of silver nitrate.
  - Chloride ion is present in the sample if a white precipitate forms.
  - Bromide ion is present in the sample if a creamy (pale yellow) precipitate forms.
  - Iodide ion is present in the sample if a yellow precipitate forms.

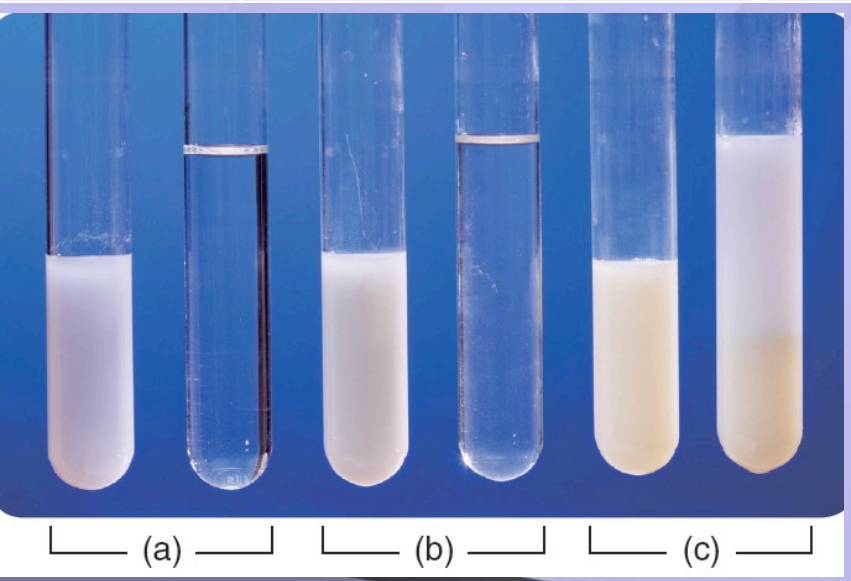


These precipitates are silver chloride (AgCl), silver bromide (AgBr) and silver iodide (AgI) (left to right)

51.4 Identifying the anion in a sample (p.13)

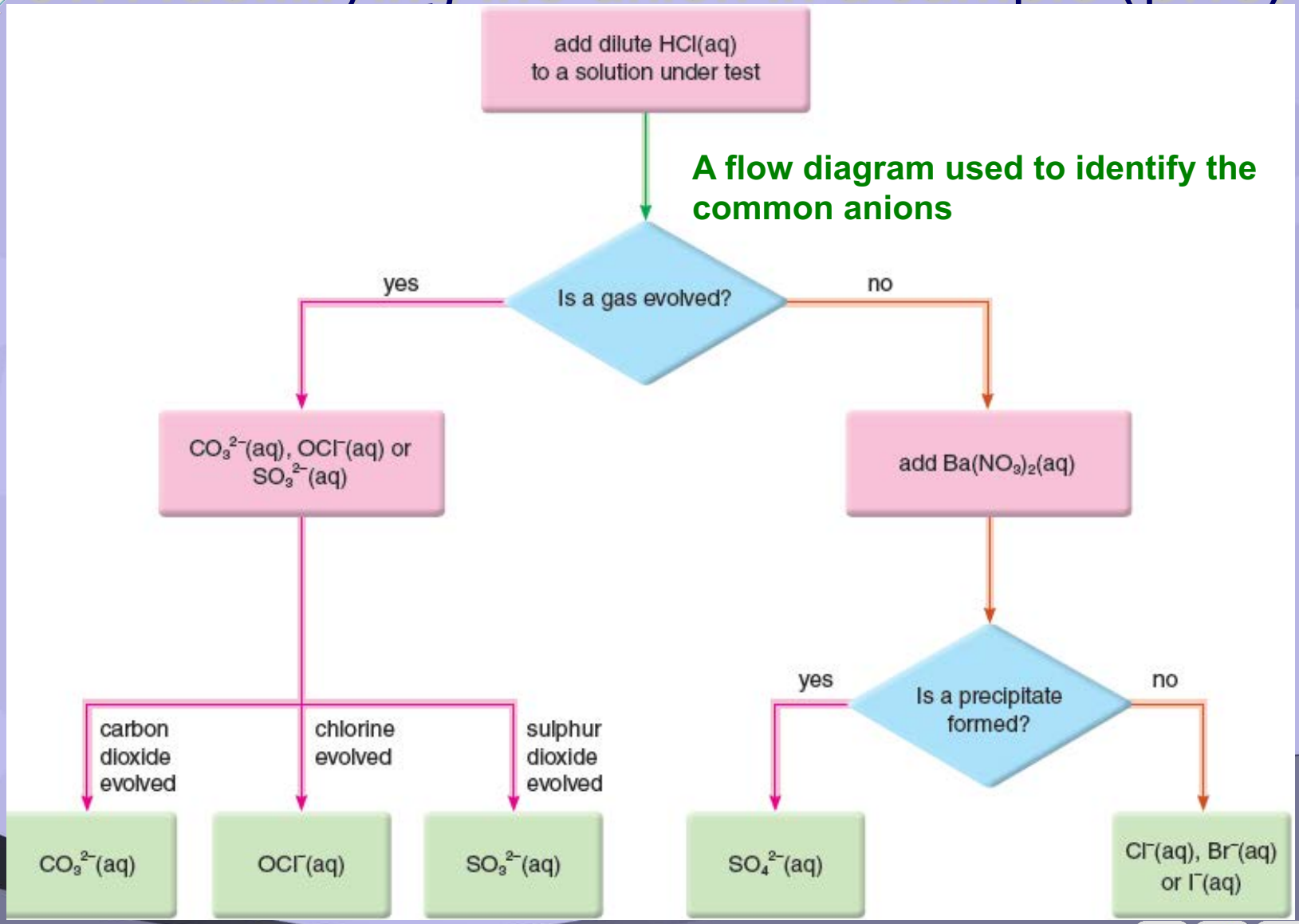
- If the colour of the precipitate is hard to distinguish, first add dilute aqueous ammonia and then concentrated aqueous ammonia, noting the solubility of the precipitate.

Halide ion	Effect of adding $AgNO_3(aq)$	Effect of adding $NH_3(aq)$
Chloride ion	white precipitate	the precipitate dissolves in dilute $NH_3(aq)$ to give a colourless solution
Bromide ion	creamy (pale yellow) precipitate	the precipitate dissolves in concentrated $NH_3(aq)$ to give a colourless solution
Iodide ion	yellow precipitate	the precipitate does not dissolve in $NH_3(aq)$ (dilute or concentrated)



The test tubes contain
(a) a precipitate of silver chloride (left), the solution after addition of dilute aqueous ammonia (right),
(b) a precipitate of silver bromide (left), the solution after addition of concentrated aqueous ammonia (right),
(c) a precipitate of silver iodide (left), silver iodide after addition of concentrated aqueous ammonia (right), which fails to dissolve the silver iodide precipitate

51.4 Identifying the anion in a sample (p.13)



A flow diagram used to identify the common anions

51.4 Identifying the anion in a sample (p.13)

Practice 51.3

1 Two jars of chemicals made in 1880s are shown below.

a) Washing soda is sodium carbonate. Describe and give the result of a chemical test to show that washing soda is a carbonate.

Add dilute hydrochloric acid to washing soda. Test any gas evolved with limewater. The limewater turns milky, showing that washing soda is a carbonate.

b) Glauber's salt is sodium sulphate. Describe and give the result of a chemical test to show that Glauber's salt is a sulphate.

Add an aqueous solution of barium chloride / barium nitrate to an aqueous solution of Glauber's salt. A white precipitate forms, showing that Glauber's salt is a sulphate.

c) Suggest why a flame test would NOT distinguish between these two chemicals.

Both would give a golden yellow flame. / Both contain sodium ion.

Identifying the anion in an unknown solid sample *Ref.*

51.4 Identifying the anion in a sample (p.13)

Practice 51.3 (continued)

2 Some scientists thought that a sample of waste water contained two sodium halides.
They added three reagents, one after the other, to the same test tube containing the waste water.
The table below shows their results.

	Reagent added	Observation
1	Aqueous solution of silver nitrate (acidified with dilute nitric acid)	A creamy (pale yellow) precipitate formed.
2	Dilute aqueous ammonia	A yellow precipitate remained.
3	Concentrated aqueous ammonia	The yellow precipitate did not dissolve.

a) i) Identify the yellow precipitate that did NOT dissolve in concentrated aqueous ammonia. Silver iodide

ii) Write the ionic equation for the formation of this precipitate from silver ion and the halide ion identified in (i).

$Ag^+(aq) + I^-(aq) \longrightarrow AgI(s)$

51.4 Identifying the anion in a sample (p.13)

Practice 51.3 (continued)

2 b) Identify the other sodium halide that must be present in this mixture of two sodium halides. Sodium chloride

c) i) Give ONE reason why the aqueous solution of silver nitrate was acidified before it was used in this test.

Any one of the following:

- To prevent the formation of other silver precipitates that would interfere with the test.
- To remove carbonate / sulphite / hydroxide ion.

ii) Explain why dilute hydrochloric acid should NOT be used to acidify the aqueous solution of silver nitrate.

Hydrochloric acid contains chloride ion.
Chloride ion would form a white precipitate / interfere with the test.

Identifying four unlabelled sample *Ref.*

51.5 Separating chemical species in a mixture (p.21)

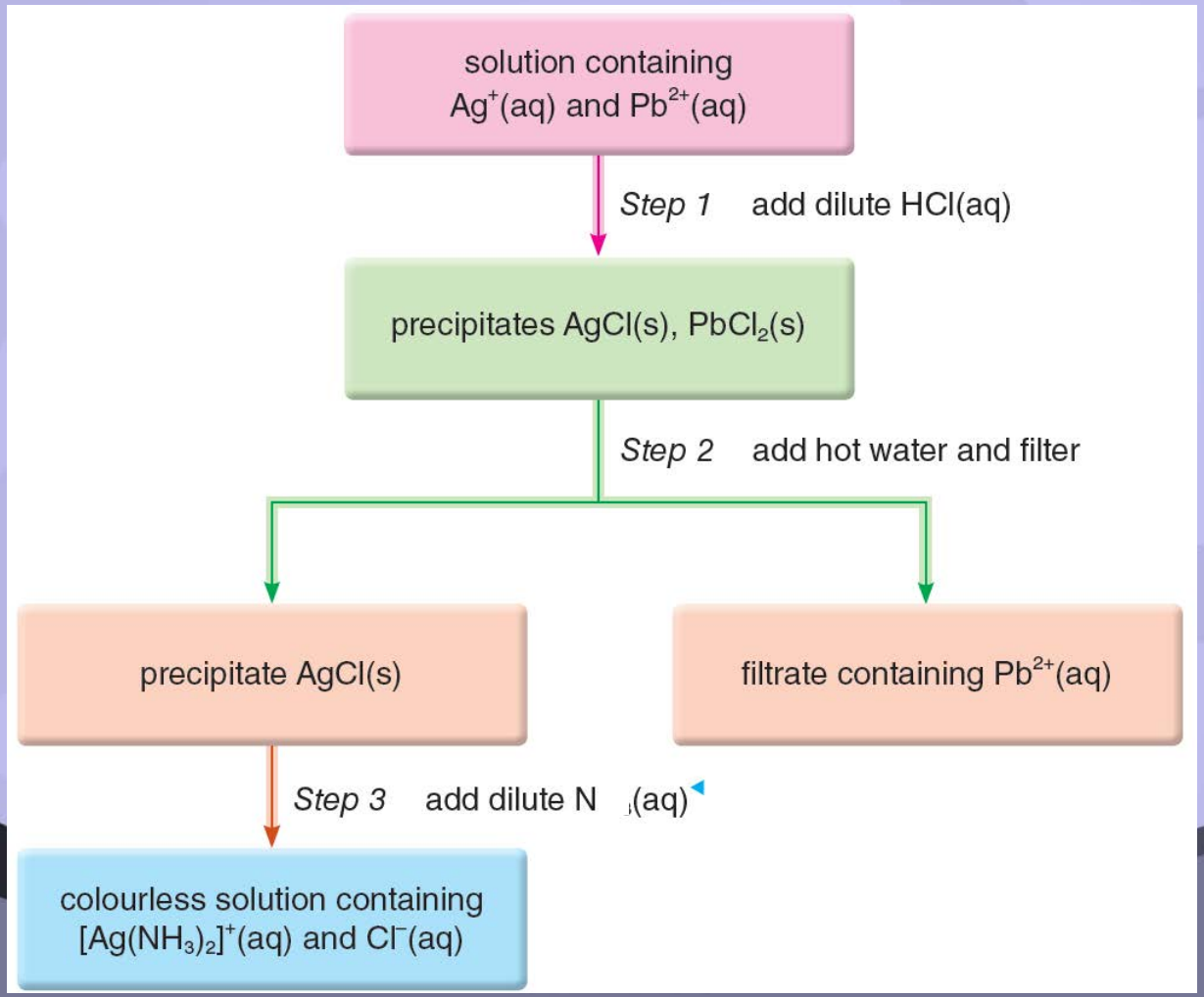
Separating cations in a mixture

- The uses of common qualitative analysis reagents.

Common qualitative analysis reagent	Use(s)
6 mol dm^{-3} HCl(aq) / 6 mol dm^{-3} H_2SO_4(aq)	• to dissolve insoluble carbonates • to dissolve insoluble hydroxides • to form insoluble chlorides / sulphates
6 mol dm^{-3} NaOH(aq) / 6 mol dm^{-3} NH_3(aq)	• to form insoluble hydroxides

51.5 Separating chemical species in a mixture (p.21)

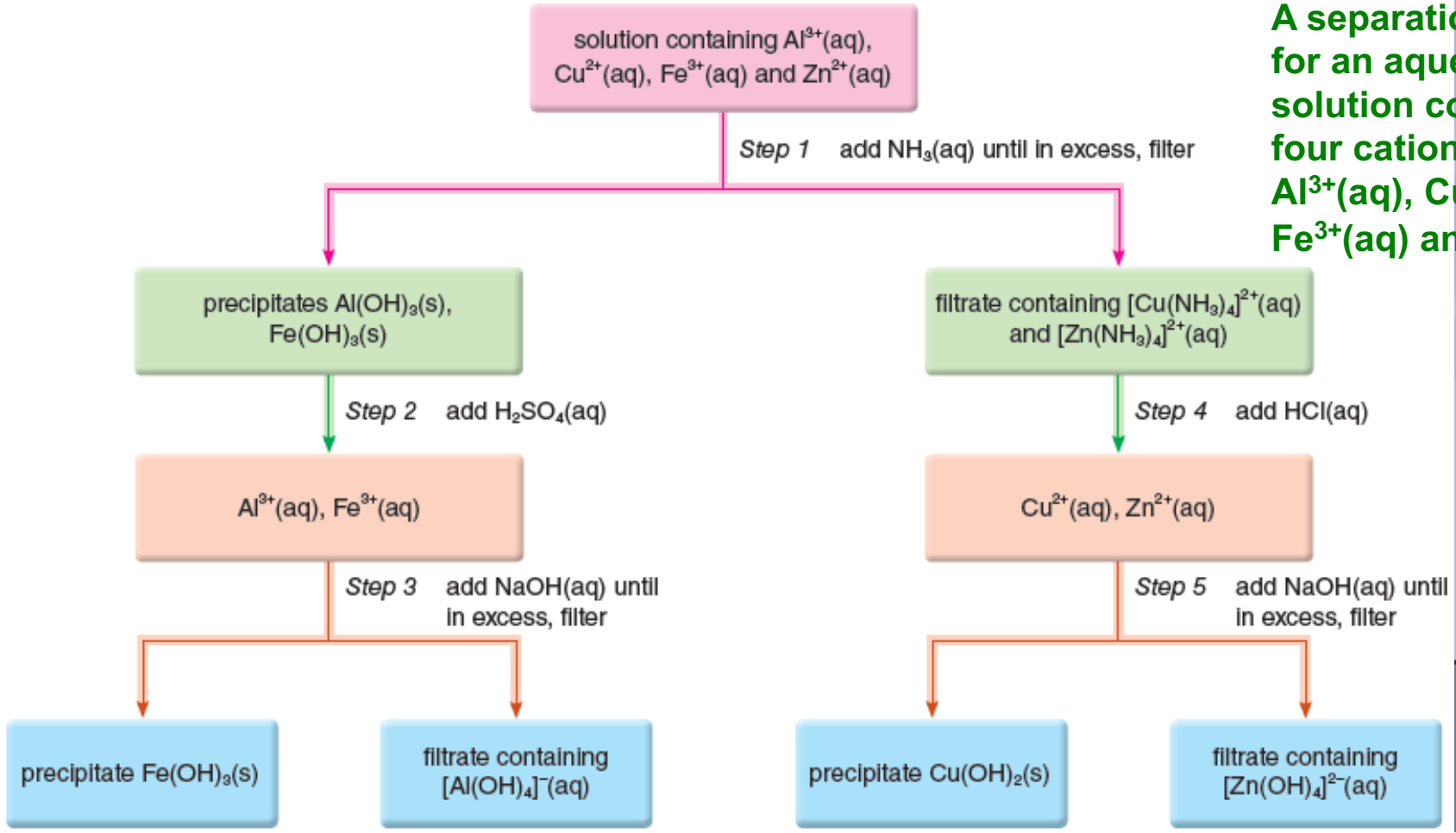
Separating two cations in an aqueous solution



A separation scheme for an aqueous solution containing two cations: $Ag^+(aq)$ and $Pb^{2+}(aq)$

51.5 Separating chemical species in a mixture (p.21)

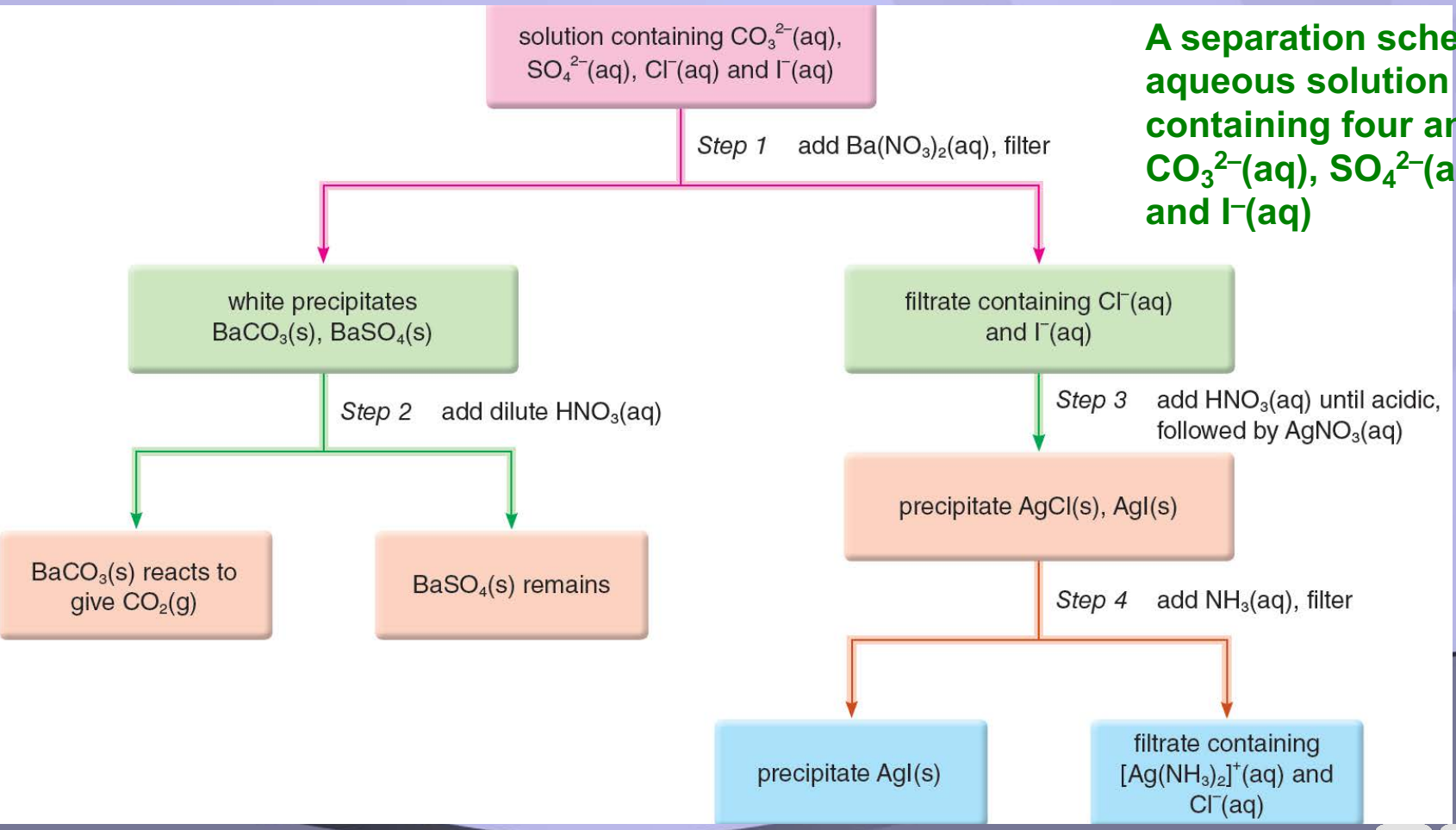
Separating four cations in an aqueous solution



A separation scheme for an aqueous solution containing four cations: $Al^{3+}(aq)$, $Cu^{2+}(aq)$, $Fe^{3+}(aq)$ and $Zn^{2+}(aq)$

51.5 Separating chemical species in a mixture (p.21)

Separating anions in a mixture



A separation scheme for an aqueous solution containing four anions: CO_3^{2-}(aq), SO_4^{2-}(aq), Cl^-(aq) and I^-(aq)

51.5 Separating chemical species in a mixture (p.21)

Practice 51.4

1 Suggest how copper powder can be obtained from a mixture of copper powder and copper(II) oxide by chemical method.

Add dilute sulphuric acid to the mixture to dissolve the copper(II) oxide.
Filter the mixture obtained to collect the copper powder.

51.5 Separating chemical species in a mixture (p.21)

Practice 51.4 (continued)

2 Suppose you are given an aqueous solution containing four cations:

$Al^{3+}(aq)$, $Ca^{2+}(aq)$, $Fe^{2+}(aq)$, $Zn^{2+}(aq)$

You are provided with the following reagents:

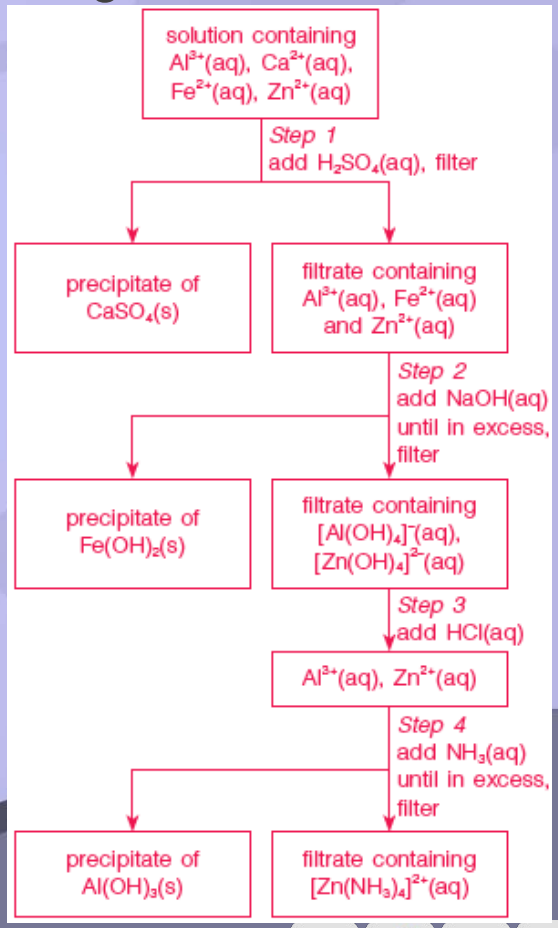
6 mol dm^{-3} HCl(aq) 6 mol dm^{-3} $H_2SO_4(aq)$

6 mol dm^{-3} $NH_3(aq)$ 6 mol dm^{-3} NaOH(aq)

Devise a separation scheme for the cations in the solution. Explain the rationale of your scheme and present it in the form of a flow diagram.

Look at the properties of the cations:

- $Ca^{2+}(aq)$ ion forms an insoluble sulphate;
- $Fe^{2+}(aq)$ ion forms an insoluble hydroxide with dilute NaOH(aq) and dilute $NH_3(aq)$;
- when mixed with NaOH(aq), $Al^{3+}(aq)$ ion and $Zn^{2+}(aq)$ ion form hydroxides that are soluble in excess NaOH(aq);
- when mixed with $NH_3(aq)$, $Zn^{2+}(aq)$ ion forms a hydroxide that is soluble in excess $NH_3(aq)$.



51.5 Separating chemical species in a mixture (p.21)

Q (Example 51.2)

Outline how you would separate $NH_4Cl(s)$, $PbCl_2(s)$ and $MgCl_2(s)$ from a mixture of the three compounds.

A

Heat the mixture. Only $NH_4Cl(s)$ sublimes. It can be collected on a cold surface.
Add water to the remaining solid mixture.
$PbCl_2(s)$ is insoluble. It can be collected by filtration. $MgCl_2(s)$ can be obtained from its solution by crystallisation.

51.6 Risk assessment of experiments (p.27)

- A hazard is something with the potential to cause harm, including injury to persons, or damage to property or equipment. A risk is the likelihood of a hazard causing harm in practice.
- To carry out a risk assessment to identify the hazards and take appropriate precautions to reduce the risk before conducting an experiment. Below are some examples.
  - Almost all organic chemicals are flammable. Thus, do not heat flasks and test tubes containing them directly with a Bunsen flame. Use a hot water bath or an electric heater (reduces risk).
  - If a chemical can be absorbed through the skin, wear protective gloves.
  - If a chemical has a harmful, irritating or toxic vapour, carry out the experiment inside a fume cupboard.
  - If a chemical is corrosive, harmful, irritating or toxic, wear protective gloves and take extra care.
  - Any substance suspected of being a carcinogen must not be used in a school laboratory.

51.6 Risk assessment of experiments (p.27)

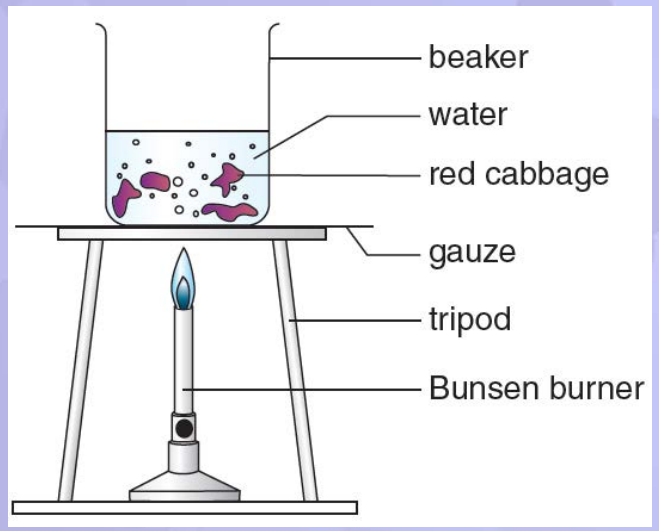
- Consider risks associated with apparatus. For example, use spirit thermometers or digital thermometers which have much lower risks instead of mercury ones. Use glass apparatus with ground glass joints, as these are safer to set up than those that use corks or bungs.
- Whenever an experiment is carried out, decide if it is safe. Take care to identify hazardous chemicals and also look for hazards arising from procedures or equipment. Carry out a risk assessment with the steps listed below.
  1 Identify the hazards involved (hazardous chemicals, procedures or equipment).
  2 Assess the risk.
  3 Decide what safety precautions to take.
  4 Find out how to dispose of any hazardous chemical properly.

51.6 Risk assessment of experiments (p.27)

- Suppose you plan to make a pH indicator from red cabbage and test the indicator, following the procedure below:

1 Boil about 100 cm^3 of water in a beaker.

2 Add three to four pieces of red cabbage to the boiling water.



Experimental set-up used to make a pH indicator from red cabbage

3 Boil for about 5 minutes. The water should have turned blue or green.

4 Turn off the Bunsen burner and allow the beaker to cool for a few minutes.

51.6 Risk assessment of experiments (p.27)

5 Place three test tubes in a rack. Half fill one with 0.05 mol dm^{-3} aqueous solution of sodium hydroxide, one with 0.05 mol dm^{-3} hydrochloric acid and one with deionised water.

6 Decant approximately 2–3 cm height of cabbage solution into each test tube.

7 Test an aqueous solution of baking soda with the cabbage solution to see if it is neutral, alkaline or acidic.

51.6 Risk assessment of experiments (p.27)

- The risk assessment of the experiment.

Hazardous chemical, procedure or equipment involved	Nature of hazard	Safety precaution(s)	Source of information
Bunsen burner	fire	• wear safety glasses • put the Bunsen burner on a fireproof mat • watch the experiment so that the water does not boil over • turn off the Bunsen burner when it is not in use	previous instruction
Lifting hot beaker	burnt fingers	• leave it to cool down a bit or use tongs	previous instruction
0.05 mol dm^{-3} aqueous solution of sodium hydroxide	irritant	• wear safety glasses • avoid contact with eyes, skin and clothes • wash hands thoroughly if come into contact with it	CLEAPSS student safety sheet
0.05 mol dm^{-3} hydrochloric acid	irritant	• wear safety glasses • avoid contact with eyes, skin and clothes • wash hands thoroughly if come into contact with it	CLEAPSS student safety sheet

Key terms (p.30)

analytical chemistry	分析化學	quantitative analysis	定量分析
qualitative analysis	定性分析		

Summary (p.31)

1 Analytical chemistry can be split into two main types — qualitative and quantitative.

2 The following table summarises the tests for some common gases and water vapour.

Gas or vapour	Test	Test result and equation (if appropriate)
Ammonia	Insert a piece of moist red litmus paper into the gas.	The moist red litmus paper turns blue.
Carbon dioxide	Pass the gas through limewater.	The limewater turns milky. $Ca(OH)_2(aq) + CO_2(g) \longrightarrow CaCO_3(s) + H_2O(l)$
Chlorine	Insert a piece of moist blue litmus paper into the gas.	The moist blue litmus paper is bleached (the litmus paper turns red first). $Cl_2(g) + H_2O(l) \rightleftharpoons HCl(aq) + HOCl(aq)$
Sulphur dioxide	Insert a piece of filter paper soaked with acidified potassium dichromate solution into the gas.	The filter paper turns from orange to green. $Cr_2O_7^{2-}(aq) + 2H^+(aq) + 3SO_2(g) \longrightarrow 2Cr^{3+}(aq) + H_2O(l) + 3SO_4^{2-}(aq)$
Hydrogen chloride	Dip a glass rod in aqueous ammonia and insert it into the gas.	Dense white fumes are formed. $NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$
Water vapour	Insert a piece of blue cobalt(II) chloride paper into the vapour.	The blue cobalt(II) chloride paper turns pink.
Hydrogen	Insert a burning splint into the gas.	The burning splint gives a 'pop' sound. $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$
Oxygen	Insert a glowing splint into the gas.	The glowing splint relights.

Summary (p.31)

3 The following table summarises results of some tests for cations.

Cation \ Test	Flame test	Addition of dilute NaOH(aq)	Addition of dilute NH_3(aq)
Aluminium ion, Al^{3+}	—	white precipitate, soluble in excess dilute NaOH(aq) to give a colourless solution	white precipitate
Ammonium ion, NH_4^+	—	colourless gas (NH_3) given off on warming	—
Calcium ion, Ca^{2+}	brick-red flame	white precipitate	—
Copper(II) ion, Cu^{2+}	bluish green flame	blue precipitate	pale blue precipitate, soluble in excess dilute NH_3(aq) to give a deep blue solution
Iron(II) ion, Fe^{2+}	—	green precipitate	green precipitate
Iron(III) ion, Fe^{3+}	—	reddish brown precipitate	reddish brown precipitate
Lead(II) ion, Pb^{2+}	—	white precipitate, soluble in excess dilute NaOH(aq) to give a colourless solution	white precipitate
Magnesium ion, Mg^{2+}	—	white precipitate	white precipitate
Potassium ion, K^+	lilac flame	—	—
Sodium ion, Na^+	golden yellow flame	—	—
Zinc ion, Zn^{2+}	—	white precipitate, soluble in excess dilute NaOH(aq) to give a colourless solution	white precipitate, soluble in excess dilute NH_3(aq) to give a colourless solution

Summary (p.31)

4 The following table summarises results of some tests for anions.

Anion \ Test	Addition of dilute HCl(aq)	Addition of $BaCl_2$(aq)	Addition of dilute HNO_3(aq), followed by $AgNO_3$(aq)	Other reagent(s)
Carbonate ion, CO_3^{2-}	colourless gas (CO_2) given off	white precipitate soluble in dilute HCl(aq) with colourless gas (CO_2) given off	—	—
Hypochlorite ion, OCl^-	pale green gas (Cl_2) given off	—	—	—
Sulphite ion, SO_3^{2-}	colourless gas (SO_2) given off	white precipitate soluble in dilute HCl(aq) with colourless gas (SO_2) given off	—	—
Sulphate ion, SO_4^{2-}	—	white precipitate insoluble in dilute HCl(aq)	—	—
Chloride ion, Cl^-	—	—	white precipitate soluble in dilute NH_3(aq)	—
Bromide ion, Br^-	—	—	creamy (pale yellow) precipitate soluble in concentrated NH_3(aq)	addition of Cl_2(aq), followed by organic solvent — an orange organic layer forms
Iodide ion, I^-	—	—	yellow precipitate	addition of Cl_2(aq), followed by organic solvent — a purple organic layer forms

Key terms (p.30)

5 Risk assessment is important in all chemical tests.

Unit Exercise (p.34)

Note: Questions are rated according to ascending level of difficulty (from 1 to 5):

 question targeted at level 3 and above;

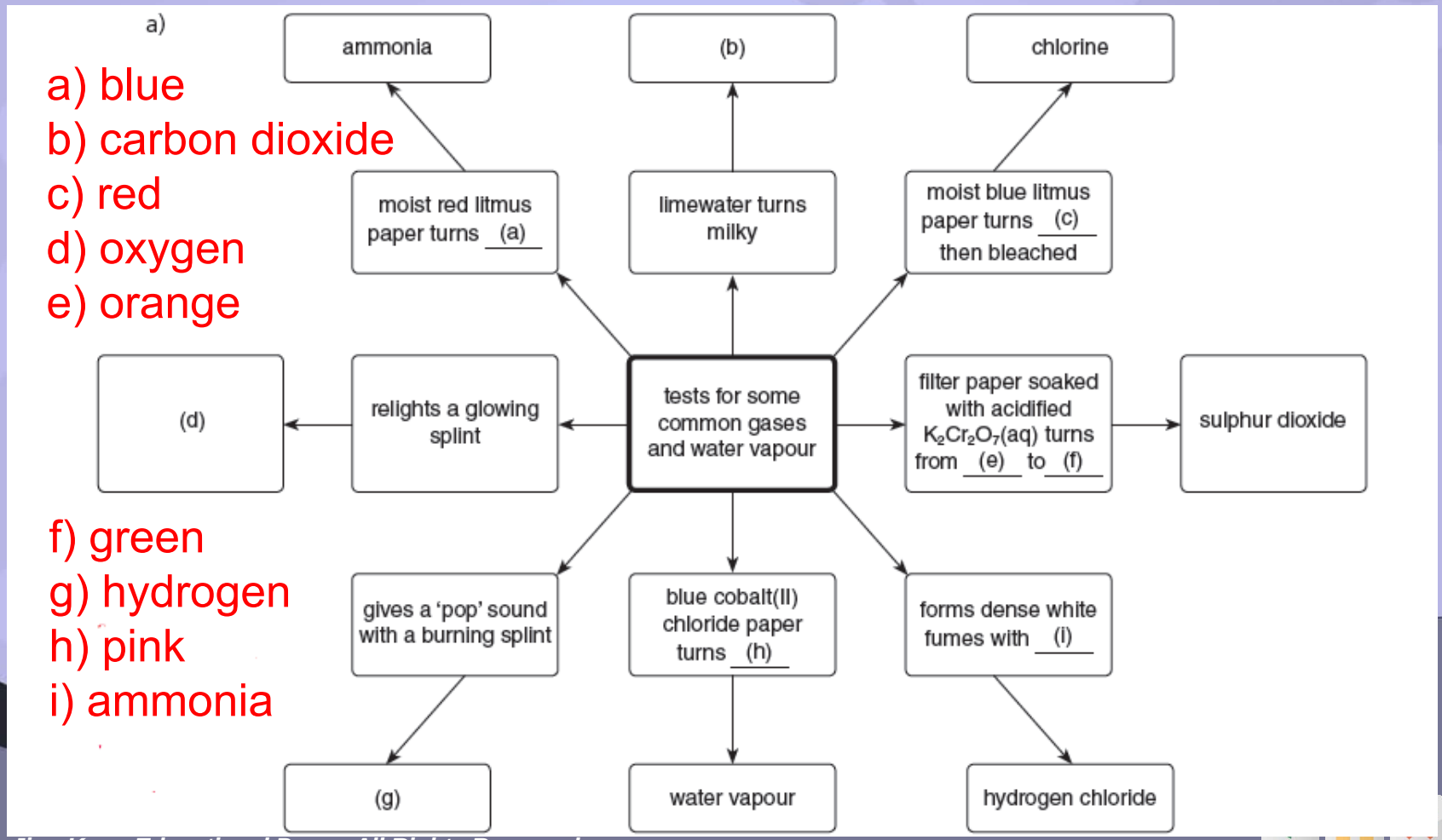
 question targeted at level 4 and above;

 question targeted at level 5.

Unit Exercise (p.34)

PART I KNOWLEDGE AND UNDERSTANDING

1 Complete the following concept maps.



a) blue
b) carbon dioxide
c) red
d) oxygen
e) orange
f) green
g) hydrogen
h) pink
i) ammonia

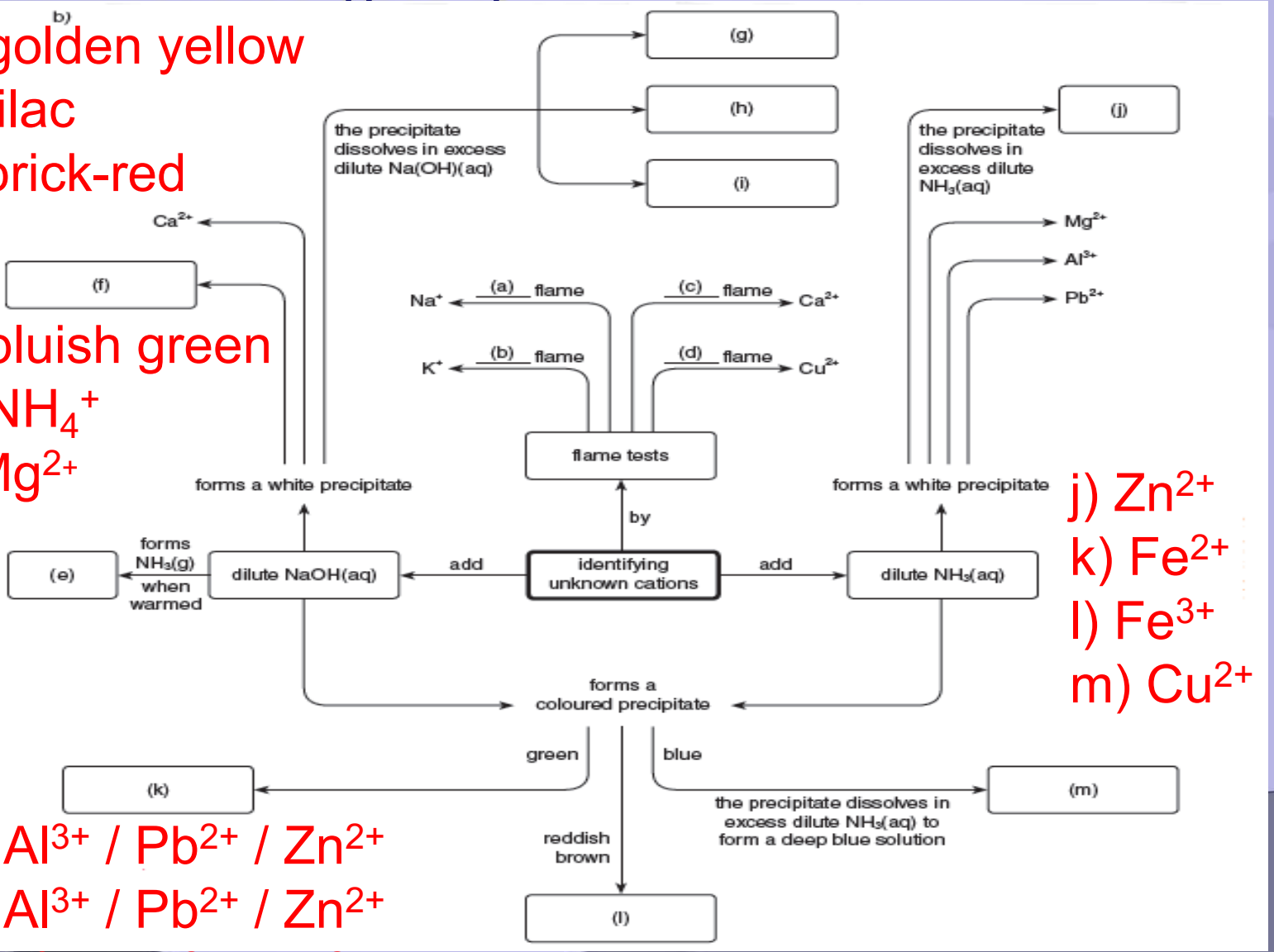
Unit Exercise (p.34)

b)

a) golden yellow

b) lilac

c) brick-red



d) bluish green

e) NH_4^+

f) Mg^{2+}

g) Al^{3+} / Pb^{2+} / Zn^{2+}

h) Al^{3+} / Pb^{2+} / Zn^{2+}

i) Al^{3+} / Pb^{2+} / Zn^{2+}

j) Zn^{2+}

k) Fe^{2+}

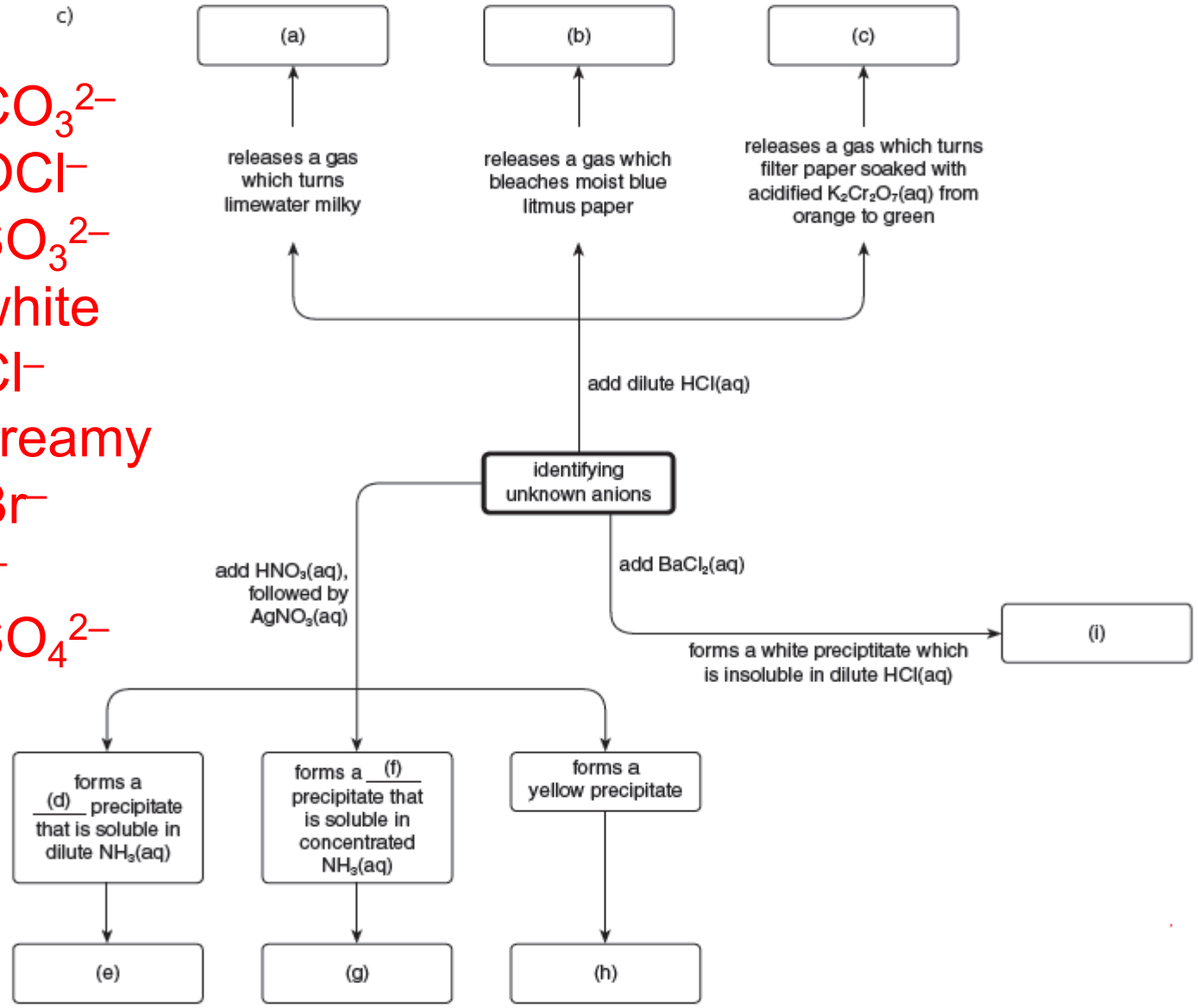
l) Fe^{3+}

m) Cu^{2+}

Unit Exercise (p.34)

a) CO_3^{2-}
b) OCl^-
c) SO_3^{2-}
d) white
e) Cl^-
f) creamy
g) Br^-
h) I^-
i) SO_4^{2-}

c)



Unit Exercise (p.34)

PART II MULTIPLE CHOICE QUESTIONS

2 Four gases, W, X, Y and Z, are known to be N_2, NO, NH_3 and O_2. It is not known which gas is which.

When gases X and Y are mixed a brown gas is formed.

Gas Y relights a glowing splint.

Gases W, X and Z extinguish a burning splint.

Gas Z turns red litmus paper blue.

Which gas is N_2?

A Gas W
B Gas X
C Gas Y
D Gas Z

Explanation:
X is NO.
Y is O_2.
Z is NH_3.

Answer: A

(OCR Advanced Level, Chem. B (Salters), Sample Question Paper, H433/01, 2016, 14)

Unit Exercise (p.34)

3 Which of the following pairs of reagents would NOT react when mixed?

A Aqueous solutions of nickel(II) sulphate and sodium carbonate

B Aqueous solution of iron(III) sulphate and sulphur dioxide gas

C Aqueous bromine and aqueous solution of ammonium chloride

D Magnesium carbonate powder and dilute hydrochloric acid

Answer: C

Unit Exercise (p.34)

4 A student adds aqueous sodium carbonate to one test tube and aqueous silver nitrate to a second test tube.
The student adds dilute sulphuric acid to each test tube.
Which row has the correct observations?

	Aqueous sodium carbonate	Aqueous silver nitrate
A	no change	precipitate
B	no change	no change
C	effervescence	no change
D	effervescence	precipitate

Answer: D

Explanation:
Aqueous solution of sodium carbonate gives carbon dioxide gas with dilute sulphuric acid.
Aqueous solution of silver nitrate gives a precipitate (Ag_2SO_4) with dilute sulphuric acid.

(OCR Advanced Subsidiary, Chem. A, H032/01,May 2016, 11)

Unit Exercise (p.34)

5 Which of the following processes would be involved in order to separate $Fe^{2+}(aq)$ ions from a mixture containing $Fe^{2+}(aq)$ and $Na^{+}(aq)$ ions?

A Performing a flame test
B Evaporating the mixture
C Using a separating funnel
D Adding NaOH(aq) to the mixture

Explanation:
$Fe^{2+}(aq)$ ions give a precipitate with NaOH(aq) while $Na^{+}(aq)$ ions do not.

Answer: D

Unit Exercise (p.34)

6 Which of the following substances can be used to distinguish between aqueous solutions of calcium nitrate and lead(II) nitrate?

A Aqueous solution of sodium carbonate
B Aqueous solution of sodium chloride
C Aqueous solution of silver nitrate
D Dilute sulphuric acid

Explanation:
Aqueous solution of lead(II) nitrate gives a precipitate with aqueous solution of sodium chloride while aqueous solution of calcium nitrate does not.

$Pb^{2+}(aq) + 2Cl^{-}(aq) \longrightarrow PbCl_2(s)$

Answer: B

Unit Exercise (p.34)

7 X is an aqueous solution. When X is added to aqueous bromine, a colourless solution results. When X is treated with dilute hydrochloric acid, a gas with an irritating smell evolves. X may be aqueous solution of

A ammonium nitrate.
B ammonium sulphate.
C sodium sulphite.
D sodium chloride.

Explanation:
Sulphite ion reduces aqueous bromine to colourless bromide.

Answer: C

Unit Exercise (p.34)

8 A teacher tests a solution that has been used by students in some experiments with potassium halides to see if it can be used with a different class.

The teacher adds silver nitrate solution to the solution that the students were using. A pale yellow precipitate is formed. The teacher adds a few drops of dilute aqueous ammonia to the precipitate. Some of the precipitate appears to dissolve and the precipitate remaining has a stronger yellow tinge. The teacher adds excess concentrated aqueous ammonia to the remaining precipitate. The precipitate does not dissolve.

Unit Exercise (p.34)

8 (continued)

What is the most likely conclusion that the teacher will reach about the solution that the students were using?

A The solution contains chloride ions.
B The solution contains bromide ions.
C The solution contains chloride and bromide ions.
D The solution contains chloride and iodide ions.

Explanation:
Silver chloride is soluble in dilute aqueous ammonia.
Silver iodide is insoluble in dilute and concentrated aqueous ammonia.

Answer: D

(OCR Advanced Level, Chem. B (Salters), Sample Question Paper, H433/01, 2016, 13)

Unit Exercise (p.34)

9 Which of the following pairs of solutions will give a precipitate when mixed?

(1) $H_2SO_4(aq)$ and $Na_2S_2O_3(aq)$
(2) $AgNO_3(aq)$ and $BaCl_2(aq)$
(3) $NiSO_4(aq)$ and $NaOH(aq)$

A (1) and (2) only
B (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

Explanation:

(1) $H_2SO_4(aq)$ and $Na_2S_2O_3(aq)$ give a precipitate (sulphur).
(2) $AgNO_3(aq)$ and $BaCl_2(aq)$ give a precipitate (silver chloride).
(3) $NiSO_4(aq)$ and $NaOH(aq)$ give a precipitate (nickel(II) hydroxide).

Answer: D

Unit Exercise (p.34)

10 An aqueous solution X gives a white precipitate when an aqueous solution of barium nitrate is added to it. The precipitate is soluble in dilute hydrochloric acid.
Which of the following ions may be present in solution X?

(1) $CO_3^{2-}(aq)$
(2) $SO_3^{2-}(aq)$
(3) $SO_4^{2-}(aq)$

A (1) and (2) only
B (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

Explanation:

(1) $CO_3^{2-}(aq)$ gives a white precipitate with $Ba(NO_3)_2(aq)$.
The precipitate ($BaCO_3$) is soluble in dilute hydrochloric acid.

(2) $SO_3^{2-}(aq)$ gives a white precipitate with $Ba(NO_3)_2(aq)$.
The precipitate ($BaSO_3$) is soluble in dilute hydrochloric acid.

Answer: A

Unit Exercise (p.34)

PART III STRUCTURED QUESTIONS

11 Suggest a test for each of the following gases.

a) Ammonia

Insert a piece of moist red litmus paper into ammonia gas. (1)

The moist red litmus paper turns blue. (1)

b) Chlorine

Insert a piece of moist blue litmus paper into chlorine gas. (1)

The moist blue litmus paper is bleached. (1)

c) Hydrogen chloride

Dip a glass rod in aqueous ammonia and insert it into hydrogen chloride gas. /

Place hydrogen chloride gas near concentrated aqueous ammonia. (1)

Dense white fumes are observed. (1)

Unit Exercise (p.34)

12 a) An ionic compound gives a brick red flame in a flame test. Suggest one cation the compound may contain.

b) Suggest a chemical test to distinguish between $K_2SO_3(aq)$ and $K_2SO_4(aq)$.

(HKDSE, Paper 2, 2018, 3(a)(i)–(ii))

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

Unit Exercise (p.34)

13 a) Suggest a test to distinguish between sodium ions and potassium ions.

b) Suggest a chemical test for detecting sulphur dioxide gas.

(HKDSE, Paper 2, 2017, 3(a)(i)–(ii))

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

Unit Exercise (p.34)

14 a) Suggest a chemical test to show the presence of $Br^-(aq)$.

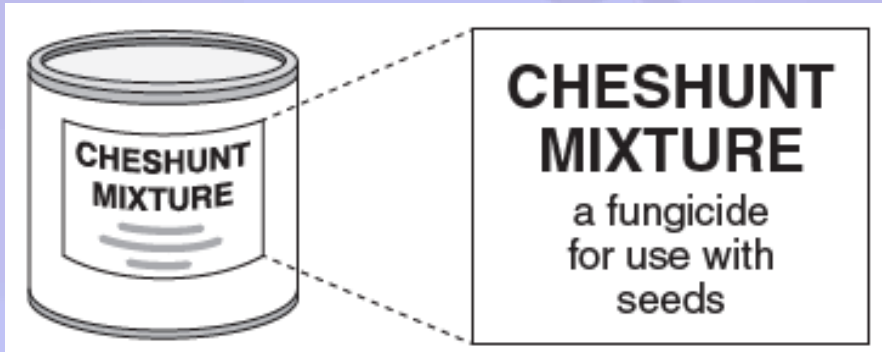
b) Suggest how copper powder can be obtained from a mixture of copper powder and iron(III) oxide by chemical method.

(HKDSE, Paper 2, 2015, 3(a)(i), (iii))

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

Unit Exercise (p.34)

15 Cheshunt mixture is a powder containing copper(II) sulphate, $CuSO_4$, and ammonium carbonate, $(NH_4)_2CO_3$.



Describe tests to show the presence of the following ions in the mixture.

a) Copper(II) ion
b) Sulphate ion
c) Ammonium ion
d) Carbonate ion

Unit Exercise (p.34)

15 (continued)

a) Any one of the following:

- Add dilute NaOH(aq) to an aqueous solution of the mixture until in excess. (1)

  A blue precipitate forms. (1)

- Add dilute $NH_3(aq)$ to an aqueous solution of the mixture until in excess. (1)

  A pale blue precipitate forms. The precipitate is soluble in excess $NH_3(aq)$, forming a deep blue solution. (1)

b) Add dilute HCl(aq) to the mixture until the solution obtained is just acidic.

Add $BaCl_2(aq)$ / $Ba(NO_3)_2(aq)$. (1)

A white precipitate forms. (1)

c) Add dilute NaOH(aq) to the mixture. Warm the mixture gently.

Test any gas evolved with moist red litmus paper. (1)

The red litmus paper turns blue. (1)

d) Add dilute HCl(aq) to the mixture.

Test any gas evolved with limewater. (1)

The limewater turns milky. (1)

Unit Exercise (p.34)

16 For each of the following pairs of chemical species, suggest a test to distinguish between them and give the expected observations.

a) AgBr(s) and AgI(s)

b) $Ba(NO_3)_2(aq)$ and $Pb(NO_3)_2(aq)$

c) $FeSO_4(aq)$ and $Fe_2(SO_4)_3(aq)$

d) NaCl(aq) and NaOCl(aq)

Unit Exercise (p.34)

16 (continued)

a) Add concentrated H_2SO_4 to each solid separately. (1)
AgBr(s) turns orange / gives orange (or brown) fumes.
AgI(s) turns black / gives purple fumes. } (1)

b) Any one of the following:
- Add HCl(aq) / KCl(aq) to each solution separately. (1)
  $Pb(NO_3)_2$(aq) gives a white precipitate ($PbCl_2$(s)).
  $Ba(NO_3)_2$(aq) gives no observable change. } (1)
- Add KI(aq) to each solution separately. (1)
  $Pb(NO_3)_2$(aq) gives a yellow precipitate (PbI_2(s)).
  $Ba(NO_3)_2$(aq) gives no observable change. } (1)

c) Any one of the following:
- Add dilute NaOH(aq) / NH_3(aq) to each solution separately. (1)
  $FeSO_4$(aq) gives a green precipitate.
  $Fe_2(SO_4)_3$(aq) gives a reddish brown precipitate. } (1)
- Bubble sulphur dioxide gas through each solution separately. (1)
  $Fe_2(SO_4)_3$(aq) changes from yellow-brown to pale green.
  $FeSO_4$(aq) gives no observable change. } (1)

d) Add dilute HCl(aq) to each solution separately. (1)
NaOCl(aq) gives a gas that bleaches moist blue litmus paper.
NaCl(aq) gives no observable change. } (1)

Unit Exercise (p.34)

17 Some tests are carried out on an inorganic compound A.

Compound A is anhydrous and has one cation and one anion.

a) Compound A gives a lilac colour in a flame test.
   i) Describe how to carry out a flame test.
   ii) Identify, by name or formula, the cation present in A.

b) When a sample of solid A is placed in a test tube and heated, a gas and a vapour are evolved. The gas turns limewater cloudy and the vapour is identified as water.
   i) Identify the gas evolved.
   ii) Give a test for the presence of water. State the positive result of the test.

c) i) Identify, by name or formula, the anion present in A.
   ii) Write the equation for the action of heat on A.

(Edexcel IAL Advanced Subsidiary, Unit 3, WCH03/01, Jun. 2016, 1)

Unit Exercise (p.34)

17 (continued)

a) i) • Moisture a clean nichrome wire by dipping it into concentrated hydrochloric acid. Then dip it into the sample under test. (1)

• Hold the wire in the hottest part of a non-luminous flame, and observe the colour of the flame. (1)

ii) Potassium ion / K^+ (1)

b) i) Carbon dioxide (1)

ii) Any one of the following:

• Test with blue cobalt(II) chloride paper. (1)
The paper turns from blue to pink. (1)

• Test with anhydrous copper(II) sulphate. (1)
The copper(II) sulphate turns from white to blue. (1)

c) i) Hydrogencarbonate ion / HCO_3^- (1)

ii) $2KHCO_3(s) \longrightarrow K_2CO_3(s) + H_2O(l) + CO_2(g)$ (1)

Unit Exercise (p.34)

i) calcium (1)
ii) dissolves in concentrated $NH_3(aq)$ to form a colourless solution (1)

18 A student carried out a series of tests on a white solid Z which contains one cation and one anion.

a) Complete the table below.

	Test	Observation	Deduction
I	Carry out a flame test on solid Z.	a brick-red flame	cation is _____(i)_____
II	Acidify an aqueous solution of Z. Then add a few drops of $AgNO_3(aq)$, followed by concentrated $NH_3(aq)$ until there is no further change.	pale yellow precipitate which _____(ii)_____ _____	anion is probably bromide
III	Add concentrated $H_2SO_4(l)$ to solid Z.	steamy fumes and vapour of _____(iii)_____ colour observed	probably hydrogen bromide and _____(iv)_____ were formed in the reaction; anion is confirmed to be bromide
IV	Test the gases formed in III with filter paper soaked with acidified $K_2Cr_2O_7(aq)$.	colour of filter paper changes from _____(v)_____ to _____(vi)_____	sulphur dioxide is present

iii) orange / brown (1)
iv) bromine (1)
v) orange (1)
vi) green (1)

Unit Exercise (p.34)

18 (continued)

b) Explain, in terms of the redox processes taking place, how sulphur dioxide was produced in *Test III*.

Hydrogen bromide is oxidised.
Sulphuric acid is reduced. (1)

Unit Exercise (p.34)

19 Treatment of 2-bromoethanol (CH_2BrCH_2OH) with aqueous solution of sodium hydroxide gives ethane-1,2-diol.

$CH_2BrCH_2OH + OH^- \longrightarrow CH_2OHCH_2OH + Br^-$

a) Aqueous solution of silver nitrate can be used to test for the presence of bromide ion.
Write the ionic equation for the reaction involved.

b) It can be difficult to distinguish between the colours of the silver halides. The use of aqueous ammonia can be very helpful.
A silver halide dissolved in concentrated aqueous ammonia to form a colourless solution.

i) Explain why this result does NOT prove conclusively that the silver halide was silver bromide.

ii) Give a further test to confirm that the silver halide is silver bromide.

Unit Exercise (p.34)

19 (continued)

a) $Ag^+(aq) + Br^-(aq) \longrightarrow AgBr(s)$ (1)

b) i) Both silver chloride and silver bromide dissolve in concentrated aqueous ammonia. (1)

ii) Any one of the following:

- Add concentrated sulphuric acid to the solid silver halide. (1)

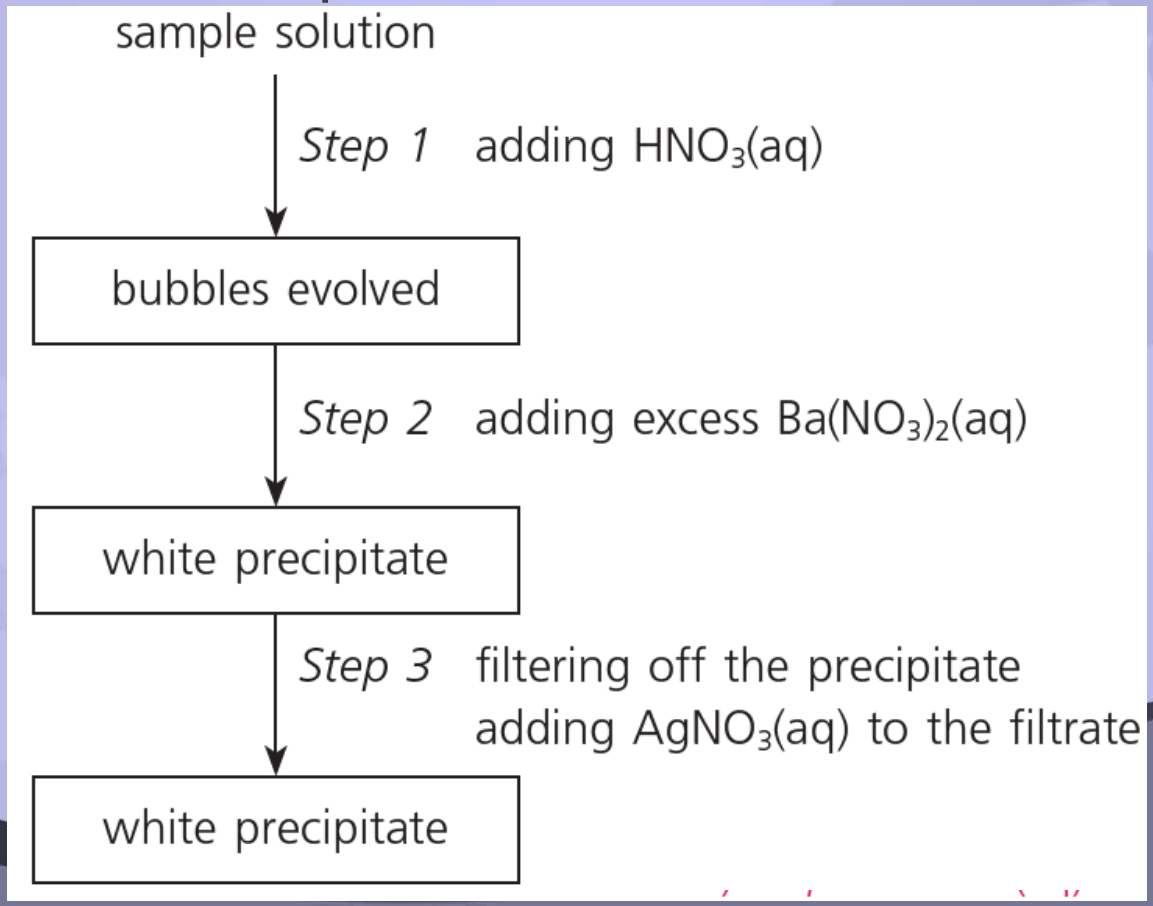
  Orange or brown fumes would be observed. (1)

- Add dilute aqueous ammonia. (1)

  If the solid does not dissolve in dilute aqueous ammonia, then it is silver bromide. (1)

Unit Exercise (p.34)

20 The flow diagram below shows a series of tests that can be used to identify carbonate, chloride and sulphate ions present in a sample solution.



Unit Exercise (p.34)

20 (continued)

a) Identify the gas evolved in *Step 1*.

Carbon dioxide (1)

b) Write ionic equations for the reactions in *Steps 2* and *3*.

Step 2 $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$ (1)

Step 3 $Ag^{+}(aq) + Cl^{-}(aq) \longrightarrow AgCl(s)$ (1)

c) Explain why the analysis must be performed in the sequence given.

Provide specific reasons to show that if the tests are done out of order, they will not identify each of the three ions. (1)

For example, if excess $Ba(NO_3)_2(aq)$ is added first, two precipitates ($BaCO_3$ and $BaSO_4$) would be obtained.

Unit Exercise (p.34)

21 A student was provided with four bottles of colourless solutions, each containing one of the following solutions:

- aqueous solution of barium nitrate;
- dilute hydrochloric acid;
- aqueous solution of lead(II) nitrate;
- aqueous solution of sodium carbonate.

The student mixed pairs of these solutions and obtained the results shown below.

Reactants	Observation
solution 1 and solution 2	bubbles
solution 2 and solution 3	white precipitate
solution 2 and solution 4	no observable change
solution 1 and solution 3	white precipitate
solution 1 and solution 4	white precipitate

Unit Exercise (p.34)

21 (continued)

a) Write a chemical equation to represent the reaction between solution 1 and solution 2.

$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$ (1)

b) Use the information to identify the four solutions. Explain your answers.

Solution 1 and solution 2 are $Na_2CO_3(aq)$ and $HCl(aq)$. (1)
Solution 1 gives a white precipitate with solution 3 and solution 4 separately. Hence it is probably $Na_2CO_3(aq)$. (1)
$CO_3^{2-}(aq) + Ba^{2+}(aq) \longrightarrow BaCO_3(s)$ (1)
$CO_3^{2-}(aq) + Pb^{2+}(aq) \longrightarrow PbCO_3(s)$ (1)
Solution 2 is $HCl(aq)$. It gives a white precipitate with solution 3. Hence solution 3 is probably $Pb(NO_3)_2(aq)$. (1)
$Pb^{2+}(aq) + 2Cl^-(aq) \longrightarrow PbCl_2(s)$ (1)
Solution 1 is $Na_2CO_3(aq)$.
Solution 2 is $HCl(aq)$.
Solution 3 is $Pb(NO_3)_2(aq)$.
Solution 4 is $Ba(NO_3)_2(aq)$.

Unit Exercise (p.34)

22 Suppose you are given an aqueous solution containing four cations:

$Ag^{+}(aq)$, $Al^{3+}(aq)$, $K^{+}(aq)$, $Mg^{2+}(aq)$

You are provided with the following reagents:

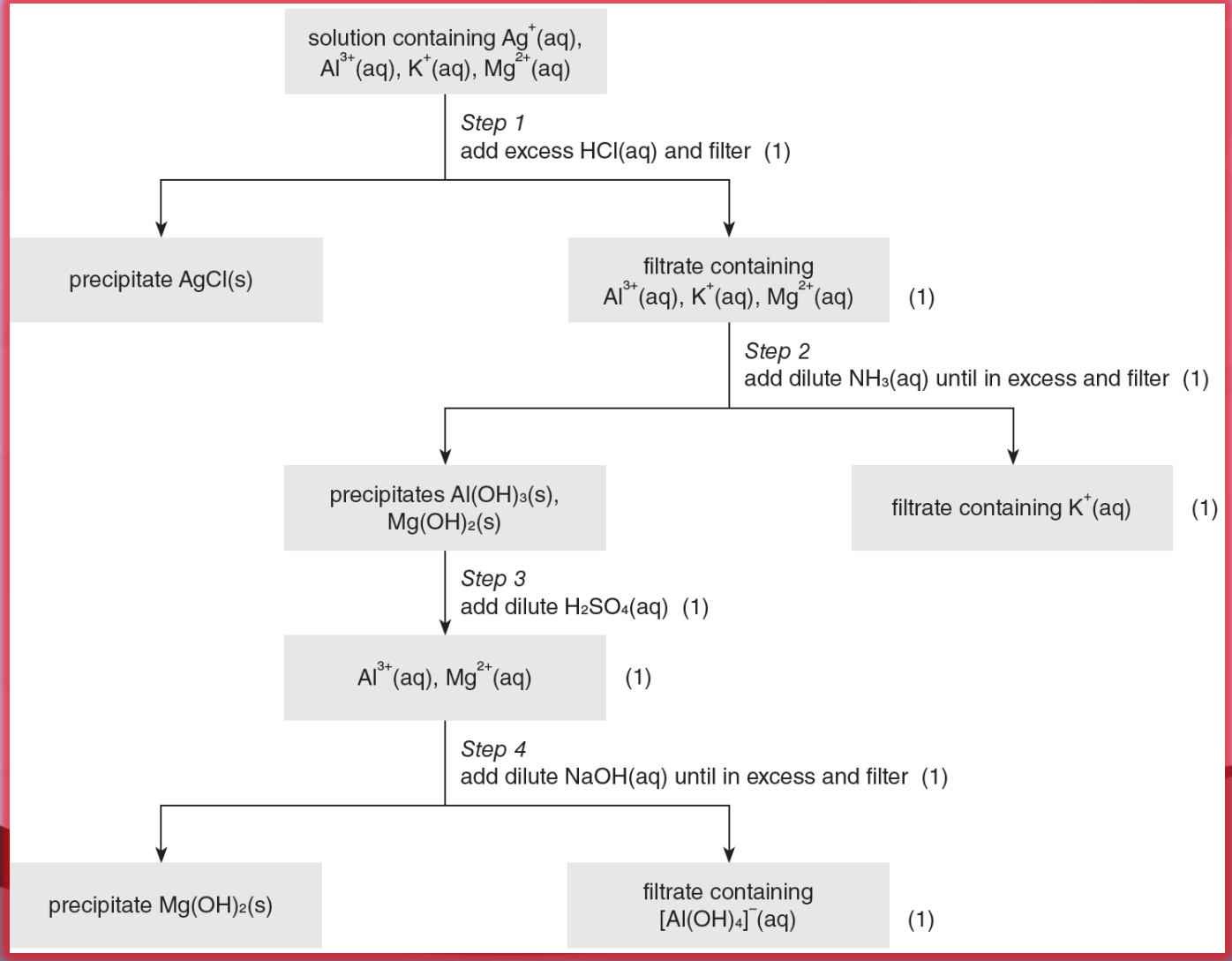
6 mol dm^{-3} HCl(aq) 6 mol dm^{-3} $H_2SO_4(aq)$

6 mol dm^{-3} $NH_3(aq)$ 6 mol dm^{-3} NaOH(aq)

Devise a separation scheme for the cations in the solution. Explain the rationale of your scheme.

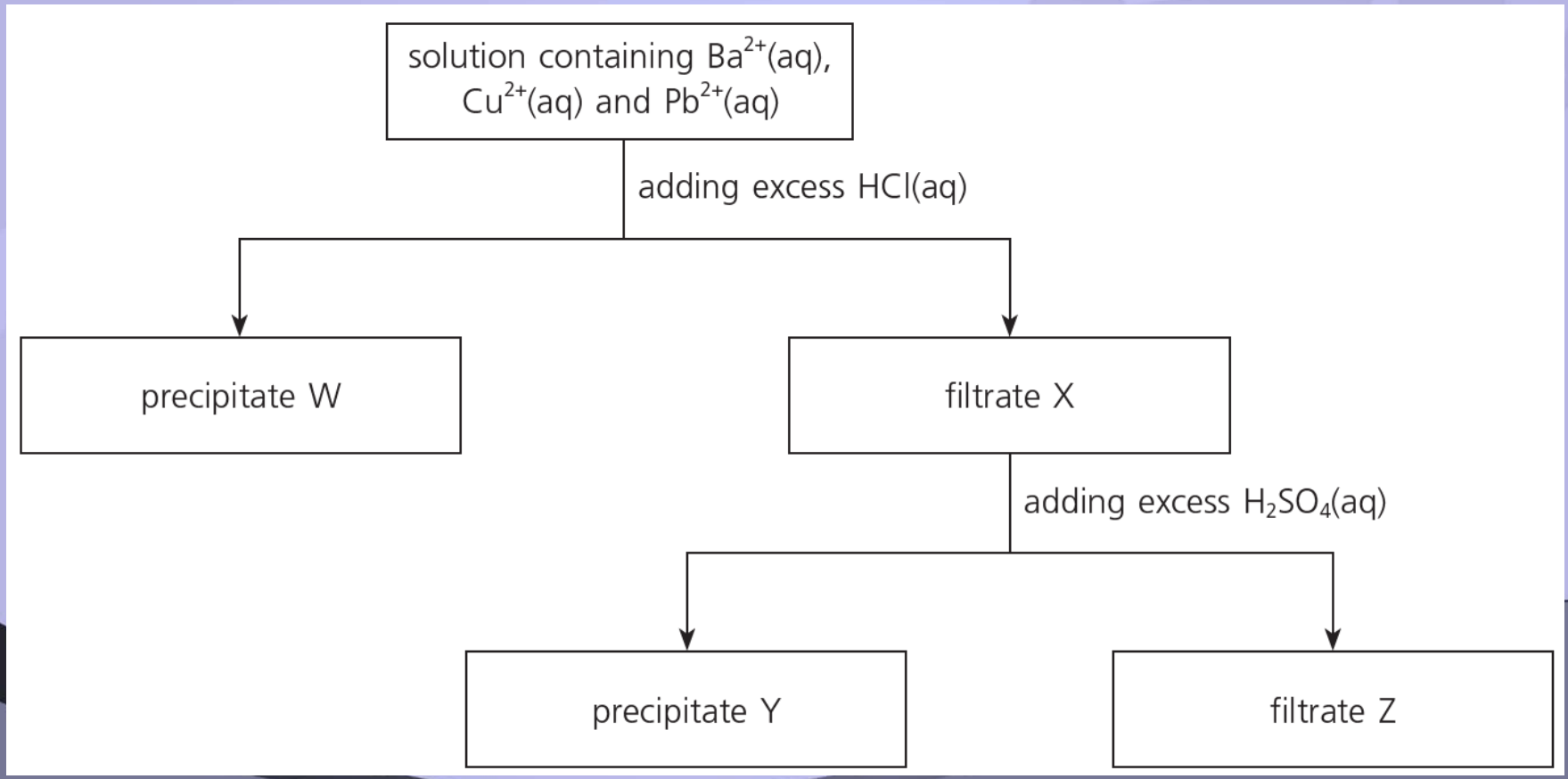
Unit Exercise (p.34)

22 (continued)



Unit Exercise (p.34)

23 A solution containing three cations, $Ba^{2+}(aq)$, $Cu^{2+}(aq)$ and $Pb^{2+}(aq)$. The flow diagram below shows a plan to separate these cations.



23 (continued)

a) Name precipitates W and Y.

Precipitate W is lead(II) chloride. (1)

Precipitate Y is barium sulphate. (1)

b) Write ionic equations for the formation of precipitates W and Y.

$Pb^{2+}(aq) + 2Cl^{-}(aq) \longrightarrow PbCl_2(s)$ (1)

$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$ (1)

c) What would be observed when dilute NaOH(aq) is added to filtrate Z? Write the ionic equation for the reaction involved.

A blue precipitate forms. (1)

$Cu^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Cu(OH)_2(s)$ (1)