Suggested answers to in-text activities and unit-end exercises

Topic 16 Unit 53

**In-text activities**

**Checkpoint (page II)**

1

<table>
<thead>
<tr>
<th>Pair of solutions</th>
<th>(i) Precipitate produced?</th>
<th>(ii) Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) CaCl₂(aq) + Na₂SO₄(aq)</td>
<td>a precipitate produced</td>
<td>CaCl₂(aq) + Na₂SO₄(aq) → CaSO₄(s) + 2NaCl(aq)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ca²⁺(aq) + SO₄²⁻(aq) → CaSO₄(aq)</td>
</tr>
<tr>
<td>(b) ZnSO₄(aq) + NaNO₃(aq)</td>
<td>no precipitate produced</td>
<td></td>
</tr>
<tr>
<td>(c) Pb(NO₃)₂(aq) + MgCl₂(aq)</td>
<td>a precipitate formed</td>
<td>Pb(NO₃)₂(aq) + MgCl₂(aq) → PbCl₂(s) + Mg(NO₃)₂(aq)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pb²⁺(aq) + 2Cl⁻(aq) → PbCl₂(s)</td>
</tr>
</tbody>
</table>

2 a) Potassium ion

b) X contains carbonate ions.

The carbonate ions in the aqueous solution of X form a precipitate (copper(II) carbonate) when mixed with copper(II) sulphate solution.

There is no reaction between aqueous solutions of potassium chloride / potassium nitrate and copper(II) sulphate.

**Checkpoint (page 17)**

1 a) Add dilute aqueous solution of sodium hydroxide / dilute aqueous ammonia to each solution.

The aqueous solution of magnesium sulphate gives a white precipitate.

Mg²⁺(aq) + 2OH⁻(aq) → Mg(OH)₂(s)

The aqueous solution of zinc sulphate gives a white precipitate that is soluble in excess alkali to form a colourless solution.

Zn²⁺(aq) + 2OH⁻(aq) → Zn(OH)₂(s)

Zn(OH)₂(s) + 2OH⁻(aq) → [Zn(OH)₄]²⁻(aq) / Zn(OH)₂(s) + 4NH₃(aq) → [Zn(NH₃)₄]²⁺(aq) + 2OH⁻(aq)

b) Warm each solid with dilute aqueous solution of sodium hydroxide.

Ammonium chloride gives a gas that turns moist red litmus paper blue (ammonia).
NH₄Cl(s) + NaOH(aq) → NaCl(aq) + H₂O(l) + NH₃(g)
There is no observable change for potassium chloride.

c) Add dilute aqueous solution of sodium hydroxide / dilute aqueous ammonia to each solution.
Aqueous solution of copper(II) nitrate gives a pale blue precipitate.
Cu²⁺(aq) + 2OH⁻ (aq) → Cu(OH)₂(s)
Aqueous solution of lead(II) nitrate gives a white precipitate.
Pb²⁺(aq) + 2OH⁻ (aq) → Pb(OH)₂(s)
OR
Add dilute hydrochloric acid to each solution.
Aqueous solution of lead(II) nitrate gives a white precipitate (lead(II) chloride).
Pb²⁺(aq) + 2Cl⁻ (aq) → PbCl₂(s)
There is no observable change for the aqueous solution of copper(II) nitrate.

2 a) i) Silver chloride
Ag⁺(aq) + Cl⁻(aq) → AgCl(s)

b) Zinc ion
Zinc ion forms with NH₃(aq) a precipitate that is soluble in excess NH₃(aq) to give a solution.
Iron(II) ion forms with NH₃(aq) a precipitate that does not dissolve in excess NH₃(aq).
Hence filtrate C contains zinc ions while precipitate D is iron(II) hydroxide.

c) Pale green
Fe²⁺(aq) ions are pale green in colour while the other ions in solution X are colourless.

Problem Solving (page 18)
Scheme 1
Distinguish lead(II) chloride and sugar from the other solids
Add water to each solid.
Only lead(II) chloride is insoluble.
Test the electrical conductivity of the four solutions obtained.
Only the aqueous solution of sugar does not conduct electricity.

Distinguish between ammonium chloride, magnesium chloride and sodium chloride
Add dilute aqueous solution of sodium hydroxide to the aqueous solution of each solid.
Only the aqueous solution of magnesium chloride gives a white precipitate (magnesium hydroxide).
Warm the remaining two solution mixtures.
Only the aqueous solution of ammonium chloride gives a gas that turns moist red litmus paper blue (ammonia).
The remaining solid is sodium chloride.

**Scheme 2**

*Distinguish ammonium chloride and sugar from the other solids*

Heat each solid strongly.
Ammonium chloride gives a white sublimate.
Only sugar chars.

*Distinguish between lead(II) chloride, magnesium chloride and sodium chloride*

Add water to each solid.
Only lead(II) chloride is insoluble.
Add dilute aqueous solution of sodium hydroxide / dilute aqueous ammonia to each aqueous solution obtained.
Only the aqueous solution of magnesium chloride gives a white precipitate (magnesium hydroxide).
The remaining solid is sodium chloride.

**Problem Solving (page 24)**

We need to look at the properties of the cations:
- Ag⁺(aq) ions form an insoluble chloride.
- Ca²⁺(aq) ions give a white precipitate with NaOH(aq) but no precipitate with NH₃(aq).
- Mg²⁺(aq) ions give a white precipitate when mixed with NaOH(aq) and NH₃(aq) separately.
- K⁺(aq) ions give no precipitate with NaOH(aq) and NH₃(aq).

The following flow diagram summarizes the separation scheme for the cations.
Checkpoint (page 37)
1 a) Any one of the following:
   - Add barium chloride solution / barium nitrate solution to the acids.
     Dilute sulphuric acid gives a white precipitate while dilute hydrochloric acid gives no precipitate.
   - Add dilute nitric acid followed by silver nitrate solution to the acids.
     Dilute hydrochloric acid gives a white precipitate while dilute sulphuric acid gives no precipitate.
   - Add calcium carbonate to excess acids.
     Calcium carbonate disappears after reaction when added to dilute hydrochloric acid.
     Calcium carbonate does not react completely with dilute sulphuric acid due to the formation of insoluble calcium sulphate on its surface.

b) Add concentrated sulphuric acid to each chemical.
   Table salt gives steamy fumes.
   White sugar chars.

c) Add aqueous chlorine to each aqueous solution.
   The aqueous solution of potassium bromide turns yellow-brown.
   There is no observable change for the aqueous solution of potassium chloride.
2. a) i) Chloride ion
   ii) \( \text{Ag}^+ (aq) + \text{Cl}^- (aq) \rightarrow \text{AgCl(s)} \)

   b) i) Zinc ion
   ii) The white precipitate formed initially was zinc hydroxide.
       Zinc hydroxide was soluble in excess aqueous ammonia due to the formation of a
       soluble complex salt.
       \[ \text{Zn}^{2+} (aq) + 2\text{OH}^- (aq) \rightarrow \text{Zn(OH)}_2(s) \]
       \[ \text{Zn(OH)}_2(s) + 4\text{NH}_3(aq) \rightarrow [\text{Zn(NH}_3)_4]^{2+}(aq) + 2\text{OH}^- (aq) \]

**Problem Solving (page 40)**

a)

<table>
<thead>
<tr>
<th>Test</th>
<th>Procedure</th>
<th>Observations</th>
<th>Deduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Describe the appearance of Y.</td>
<td>Y is a white crystalline solid.</td>
<td>( Y ) does not contain coloured transition metal ions.</td>
</tr>
<tr>
<td>2</td>
<td>Carry out a flame test on Y.</td>
<td>A lilac flame appears.</td>
<td>( Y ) contains potassium ions.</td>
</tr>
<tr>
<td>3</td>
<td>Prepare an aqueous solution of Y.</td>
<td>A colourless solution forms.</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>a) Add dilute nitric acid followed by aqueous solution of silver nitrate. Divide the reaction mixture into two separate portions.</td>
<td>A creamy white precipitate forms.</td>
<td>( Y ) contains halide ions.</td>
</tr>
<tr>
<td></td>
<td>b) To the first portion, add excess dilute aqueous ammonia.</td>
<td>The precipitate does not dissolve.</td>
<td>( Y ) does not contain chloride ions.</td>
</tr>
<tr>
<td></td>
<td>c) To the second portion, add excess concentrated aqueous ammonia.</td>
<td>The precipitate dissolves, giving a colourless solution.</td>
<td>( Y ) contains bromide ions.</td>
</tr>
</tbody>
</table>

b) \( Y \) contains potassium ions because \( Y \) gives a lilac flame in the flame test.
\( Y \) contains halide ions because the aqueous solution of \( Y \) gives a creamy white precipitate with
acidified aqueous solution of silver nitrate.
The precipitate formed is silver bromide which does not dissolve in excess dilute aqueous ammonia but soluble in very concentrated aqueous ammonia.
Thus, \( Y \) contains bromide ions.

**Checkpoint (page 44)**

**Experiment title: Investigating the chemical properties of hex-1-ene**
### Hazardous chemical, procedure or equipment involved

<table>
<thead>
<tr>
<th>Hazardous chemical, procedure or equipment involved</th>
<th>Nature of hazard</th>
<th>Safety precautions</th>
<th>Source of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hex-1-ene</td>
<td>flammable, irritant</td>
<td>• wear safety glasses and protective gloves&lt;br&gt;• keep the reagent bottle tightly closed&lt;br&gt;• ensure good ventilation in the laboratory&lt;br&gt;• dispose of hex-1-ene in a waste bottle inside the fume cupboard</td>
<td>Material Safety Data Sheets (MSDS)</td>
</tr>
<tr>
<td>Aqueous bromine</td>
<td>harmful</td>
<td>• keep aqueous bromine inside the fume cupboard&lt;br&gt;• wear safety glasses and protective gloves&lt;br&gt;• carry out the experiment inside the fume cupboard&lt;br&gt;• wash affected areas with plenty of water if spilt on the skin or clothes; report the accident to the teacher&lt;br&gt;• dispose of aqueous bromine in a waste bottle inside the fume cupboard</td>
<td>Material Safety Data Sheets (MSDS)</td>
</tr>
<tr>
<td>Shaking the solution mixtures</td>
<td>spillage may occur if shaken too vigorously</td>
<td>• do not shake too vigorously</td>
<td>previous instruction</td>
</tr>
</tbody>
</table>

### Unit-end exercises (pages 49 – 57)

Answers for the HKCEE and HKALE questions are not provided.

1. a) Clean the end of a nichrome wire by dipping it into concentrated hydrochloric acid and then heat it in the Bunsen flame.
   
   Dip the nichrome wire into concentrated hydrochloric acid and then into the solid under test.
   
   Put the end of the wire in the Bunsen flame again. Observe the colour of the flame.

   b) A calcium salt gives a brick-red flame.
      
      A sodium salt gives a golden yellow flame.
### Cation Action

<table>
<thead>
<tr>
<th>Cation</th>
<th>Action of NaOH(aq)</th>
<th>Action of NH₃(aq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium ion, Al³⁺(aq)</td>
<td>white precipitate, soluble in excess NaOH(aq) to give a colourless solution</td>
<td>white precipitate</td>
</tr>
<tr>
<td>Ammonium ion, NH₄⁺(aq)</td>
<td>colourless gas (NH₃) given off on warming</td>
<td>—</td>
</tr>
<tr>
<td>Calcium ion, Ca²⁺(aq)</td>
<td>white precipitate</td>
<td>—</td>
</tr>
<tr>
<td>Copper(II) ion, Cu²⁺(aq)</td>
<td>blue precipitate</td>
<td>blue precipitate, soluble in excess NH₃(aq) to give a deep blue solution</td>
</tr>
<tr>
<td>Iron(II) ion, Fe²⁺(aq)</td>
<td>green precipitate, turning brown on standing</td>
<td>green precipitate, turning brown on standing</td>
</tr>
<tr>
<td>Iron(III) ion, Fe³⁺(aq)</td>
<td>reddish brown precipitate</td>
<td>reddish brown precipitate</td>
</tr>
<tr>
<td>Lead(II) ion, Pb²⁺(aq)</td>
<td>white precipitate, soluble in excess NaOH(aq) to give a colourless solution</td>
<td>white precipitate</td>
</tr>
<tr>
<td>Zinc ion, Zn²⁺(aq)</td>
<td>white precipitate, soluble in excess NaOH(aq) to give a colourless solution</td>
<td>white precipitate, soluble in excess NH₃(aq) to give a colourless solution</td>
</tr>
</tbody>
</table>

### Gas / Vapour Test

<table>
<thead>
<tr>
<th>Gas / Vapour</th>
<th>Test</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>Insert a piece of moist red litmus paper into the gas.</td>
<td>It turns moist red litmus paper blue.</td>
</tr>
<tr>
<td></td>
<td>Dip a glass rod in dilute hydrochloric acid and insert it into the gas.</td>
<td>Dense white fumes are formed.</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Bubble the gas through limewater.</td>
<td>The limewater turns milky.</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Insert a piece of moist blue litmus paper into the gas.</td>
<td>Chlorine turns the moist blue litmus paper red and then bleaches it.</td>
</tr>
<tr>
<td>Bromine</td>
<td>Insert a piece of moist blue litmus paper into the vapour.</td>
<td>Bromine turns the moist blue litmus paper red and then bleaches it.</td>
</tr>
<tr>
<td>Iodine</td>
<td>Insert a piece of moist starch paper into the vapour.</td>
<td>The moist starch paper turns blue-black.</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Insert a burning splint into the gas.</td>
<td>A ‘pop’ sound is heard.</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Insert a glowing splint into the gas.</td>
<td>The glowing splint relights.</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Hydrogen halides</th>
<th>Dip a glass rod in aqueous ammonia and insert it into the gas.</th>
<th>Dense white fumes are formed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur dioxide</td>
<td>Insert a piece of filter paper soaked with acidified potassium dichromate solution into the gas.</td>
<td>The paper turns from orange to green.</td>
</tr>
<tr>
<td>Water vapour</td>
<td>Insert a piece of blue cobalt(II) chloride paper into the vapour.</td>
<td>The blue cobalt(II) chloride turns pink.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anion</th>
<th>Action of HCl(aq)</th>
<th>Action of concentrated H₂SO₄(aq)</th>
<th>Action of HCl(aq), followed by BaCl₂(aq)</th>
<th>Action of dilute HNO₃(aq), followed by AgNO₃(aq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonate ion, CO₃²⁻</td>
<td>colourless gas (CO₂) given off</td>
<td>vigorous reaction, colourless gas (CO₂) given off</td>
<td>colourless gas (CO₂) given off</td>
<td>—</td>
</tr>
<tr>
<td>Hypochlorite ion, OCl⁻</td>
<td>greenish yellow gas (Cl₂) given off</td>
<td>—</td>
<td>greenish yellow gas (Cl₂) given off</td>
<td>—</td>
</tr>
<tr>
<td>Sulphite ion, SO₃²⁻</td>
<td>colourless gas (SO₂) given off</td>
<td>vigorous reaction, colourless gas (SO₂) given off</td>
<td>colourless gas (SO₂) given off</td>
<td>—</td>
</tr>
<tr>
<td>Sulphate ion, SO₄²⁻</td>
<td>—</td>
<td>—</td>
<td>white precipitate insoluble in dilute HCl(aq)</td>
<td>—</td>
</tr>
<tr>
<td>Chloride ion, Cl⁻</td>
<td>—</td>
<td>steamy fumes (HCl) given off</td>
<td>—</td>
<td>white precipitate soluble in NH₃(aq)</td>
</tr>
<tr>
<td>Bromide ion, Br⁻</td>
<td>—</td>
<td>reddish brown vapour (HBr, Br₂ and SO₂) given off</td>
<td>—</td>
<td>creamy precipitate soluble in concentrated NH₃(aq)</td>
</tr>
<tr>
<td>Iodide ion, I⁻</td>
<td>—</td>
<td>purple vapour (I₂, SO₂ and H₂S) given off</td>
<td>—</td>
<td>yellow precipitate</td>
</tr>
</tbody>
</table>

5 a) i) Flammable and toxic  
ii) Corrosive  
iii) Oxidizing  
iv) Corrosive
b) i) • As methanol is flammable, keep the reagent bottle tightly closed.
   • There should be no naked flame in the laboratory during an experiment with methanol.
ii) • Wear safety glasses and protective gloves.
   • Concentrated sulphuric acid is highly corrosive. It gives severe burns to the skin. Handle with great care.
   • NEVER add water to concentrated sulphuric acid.
   • If you spill any acid on your skin or clothes, wash it off immediately with plenty of water. Then report the accident to your teacher.
   • Wash containers of concentrated sulphuric acid with great care; do not add water to the acid directly.
   • Dispose of the acid in a waste bottle inside the fume cupboard.

6 a) A pale blue precipitate forms initially.
   The precipitate dissolves in excess dilute aqueous ammonia to form a deep blue solution.
b) Reddish brown vapour is formed.
   The vapour condenses to a reddish brown liquid.
c) Purple vapour which condenses to a black solid is formed.
d) Anhydrous cobalt(II) chloride paper turns from blue to pink.

7

<table>
<thead>
<tr>
<th>Pair of solutions</th>
<th>(i) Precipitate produced?</th>
<th>(ii) Colour of precipitate</th>
<th>(ii) Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) AgNO₃(aq) + HCl(aq)</td>
<td>a precipitate produced</td>
<td>white</td>
<td>Ag⁺(aq) + Cl⁻(aq) → AgCl(s)</td>
</tr>
<tr>
<td>(b) Ca(NO₃)₂(aq) + MgSO₄(aq)</td>
<td>a precipitate produced</td>
<td>white</td>
<td>Ca²⁺(aq) + SO₄²⁻(aq) → CaSO₄(s)</td>
</tr>
<tr>
<td>(c) KCl(aq) + NH₃(aq)</td>
<td>no precipitate produced</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>(d) ZnSO₄(aq) + K₂CO₃(aq)</td>
<td>a precipitate produced</td>
<td>white</td>
<td>Zn²⁺(aq) + CO₃²⁻(aq) → ZnCO₃(s)</td>
</tr>
</tbody>
</table>

8 a) CuCO₃ gives a black solid (CuO) upon heating.
   
   CuCO₃(s) → CuO(s) + CO₂(g)

b) FeSO₄•7H₂O gives a colourless vapour that turns blue cobalt(II) chloride paper pink (water vapour) upon heating.
   
   FeSO₄•7H₂O(s) → FeSO₄(s) + 7H₂O(g)

c) Na₂S₂O₃ gives a colourless gas that turns acidified aqueous solution of potassium
d) CuCO₃ gives a gas that turns limewater milky (carbon dioxide) upon reaction with dilute hydrochloric acid.
\[ \text{CuCO}_3(s) + 2\text{HCl}(aq) \rightarrow \text{CuCl}_2(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g) \]

e) NaOCl gives a gas that bleaches moist blue litmus paper (chlorine) upon reaction with dilute hydrochloric acid.
\[ \text{NaOCl}(s) + 2\text{HCl}(aq) \rightarrow \text{NaCl}(aq) + \text{H}_2\text{O}(l) + \text{Cl}_2(g) \]

f) KI gives a purple vapour (iodine) upon reaction with concentrated sulphuric acid.
\[ \text{NaI}(s) + \text{H}_2\text{SO}_4(l) \rightarrow \text{NaHSO}_4(s) + \text{HI}(g) \]
\[ 8\text{HI}(g) + \text{H}_2\text{SO}_4(l) \rightarrow 4\text{I}_2(s) + \text{H}_2\text{S}(g) + 4\text{H}_2\text{O}(l) \]

9 a) Add a few drops of dilute aqueous solution of sodium hydroxide to an aqueous solution of the salt.
A pale blue precipitate forms.

b) Warm the salt with dilute aqueous sodium hydroxide solution.
Ammonia gas that turns moist red litmus paper blue is liberated.

c) Add an aqueous solution of barium chloride followed by dilute hydrochloric acid to an aqueous solution of the salt.
A white precipitate (barium sulphate) forms.

d) Heat the salt in a boiling tube. The water vapour evolved turns blue cobalt(II) chloride paper pink.

10 a) Warm each sample with dilute aqueous solution of sodium hydroxide.
Ammonium sulphate gives a gas that turns moist red litmus paper blue (ammonia).
\[ (\text{NH}_4)_2\text{SO}_4(s) + 2\text{NaOH}(aq) \rightarrow \text{Na}_2\text{SO}_4(aq) + 2\text{H}_2\text{O}(l) + 2\text{NH}_3(g) \]
Sodium sulphate just dissolves.

b) Conduct a flame test.
Potassium nitrate gives a lilac flame.
Sodium nitrate gives a golden yellow flame.

c) Add dilute aqueous solution of sodium hydroxide to the aqueous solution of each sample.
Copper(II) chloride solution gives a pale blue precipitate.
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\[ \text{Cu}^{2+}(aq) + 2\text{OH}^-(aq) \rightarrow \text{Cu(OH)}_2(s) \]
Iron(II) sulphate solution gives a green precipitate.

\[ \text{Fe}^{2+}(aq) + 2\text{OH}^-(aq) \rightarrow \text{Fe(OH)}_2(s) \]

\(d)\) Add dilute hydrochloric acid to each sample.
Magnesium carbonate gives a gas that turns limewater milky (carbon dioxide).
\[ \text{MgCO}_3(s) + 2\text{HCl}(aq) \rightarrow \text{MgCl}_2(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g) \]
Magnesium chloride just dissolves.

e) Add concentrated sulphuric acid to each sample.
Sodium bromide gives a reddish brown vapour that forms dense white fumes with aqueous ammonia (hydrogen bromide + bromine vapour). The vapour condenses to a reddish brown liquid.
\[ \text{NaBr}(s) + \text{H}_2\text{SO}_4(l) \rightarrow \text{NaHSO}_4(s) + \text{HBr}(g) \]
\[ 2\text{HBr}(g) + \text{H}_2\text{SO}_4(l) \rightarrow \text{Br}_2(g) + \text{SO}_2(g) + 2\text{H}_2\text{O}(l) \]
Sodium iodide gives a purple vapour that condenses to a black solid (iodine).
\[ \text{NaI}(s) + \text{H}_2\text{SO}_4(l) \rightarrow \text{NaHSO}_4(s) + \text{HI}(g) \]
\[ 8\text{HI}(g) + \text{H}_2\text{SO}_4(l) \rightarrow 4\text{I}_2(s) + \text{H}_2\text{S}(g) + 4\text{H}_2\text{O}(l) \]
f) Add dilute hydrochloric acid to each sample.
Potassium sulphite gives a colourless gas that turns acidified aqueous solution of potassium dichromate green (sulphur dioxide).
\[ \text{K}_2\text{SO}_3(s) + 2\text{HCl}(aq) \rightarrow 2\text{KCl}(aq) + \text{H}_2\text{O}(l) + \text{SO}_2(g) \]
Potassium sulphate just dissolves.

11 a) i) A white precipitate forms.

\[ \text{Ag}^+(aq) + \text{Cl}^-(aq) \rightarrow \text{AgCl}(s) \]

iii) \(\text{AgCl}(s)\) is readily soluble in aqueous ammonia.
\(\text{AgBr}(s)\) is soluble in very concentrated aqueous ammonia.
\(\text{AgI}(s)\) is insoluble in aqueous ammonia.

b) i) \(\begin{array}{c|c}
\text{Cl}_2 & 0 \\
\text{HOCl} & +1 \\
\text{HCl} & -1 \\
\end{array} \)

ii) Tap water contains chloride ions.
13  a) A: Potassium sulphite  
   B: Potassium chloride  
   C: Sulphur dioxide  
   D: Barium sulphite  

   b) i) \( \text{K}_2\text{SO}_3(\text{aq}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{KCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{SO}_2(\text{g}) \)  

   ii) \( \text{Ba}^{2+}(\text{aq}) + \text{SO}_3^{2-}(\text{aq}) \rightarrow \text{BaSO}_3(\text{s}) \)  

   iii) \( 3\text{SO}_2(\text{aq}) + \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow 3\text{SO}_4^{2-}(\text{aq}) + 2\text{Cr}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \)  

   c) A colourless solution would form.  

d) Any soluble carbonate / sulphate  

e) i) Neutralization  

   ii) \( \text{SO}_2(\text{g}) + 2\text{NaOH}(\text{aq}) \rightarrow \text{Na}_2\text{SO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \)  

   f)  

14  a) A — ammonium sulphate  
   B — ammonia  
   C — barium sulphate  

   b) D — potassium bromide  
   E — bromine  
   F — sulphur dioxide  

15  a) i) Iron(II) ion  

   ii) Iron(II) hydroxide is oxidized to iron(III) hydroxide on standing in air.  

   iii) A green precipitate (FeCO_3(s)) forms.  

   b) i) Calcium ion
ii) \[ \text{Ca}^{2+}(aq) + 2\text{OH}^- (aq) \rightarrow \text{Ca(OH)}_2(s) \]

c) Add dilute aqueous ammonia to each solution.
Zinc ion gives a white precipitate that is soluble in excess dilute aqueous ammonia.
Lead(II) ion gives a white precipitate that is insoluble in excess dilute aqueous ammonia.

d)

16 a) Calcium sulphate
The brick-red flame in flame test indicates that compound D contains calcium ion.
Compound D is insoluble in water, so it should be either calcium sulphate or calcium carbonate.
It does not react with dilute hydrochloric acid, so it should be calcium sulphate.

b) i) Copper(II) hydroxide / copper(II) oxide
B dissolves to give a blue solution, so it should contain copper(II) ion.
As B is insoluble in water, it might be a carbonate, hydroxide or an oxide. As no gas is evolved in its reaction with dilute hydrochloric acid, it should not be a carbonate.

ii) \[ \text{Cu(OH)}_2(s) + 2\text{H}^+(aq) \rightarrow \text{Cu}^{2+}(aq) + 2\text{H}_2\text{O}(l) \]
   \[ \text{Cu}^{2+}(aq) + \text{H}_2\text{O}(l) \]


c) i) A contains ammonium ion.
\[ \text{NH}_4^+(aq) + \text{OH}^- (aq) \rightarrow \text{NH}_3(g) + \text{H}_2\text{O}(l) \]

ii) Chloride ion
It gives a white precipitate with acidified aqueous solution of silver nitrate.
\[ \text{NH}_4\text{Cl}(aq) + \text{AgNO}_3(aq) \rightarrow \text{AgCl}(s) + \text{NH}_4\text{NO}_3(aq) \]

d) i) Bromide ion

ii) The solution turns yellow-brown.
Chlorine is a stronger oxidizing agent than bromine. It oxidizes bromide ion to bromine.
\[ \text{Cl}_2(g) + 2\text{Br}^- (aq) \rightarrow 2\text{Cl}^-(aq) + \text{Br}_2(aq) \]

e) Conduct a flame test.
Sodium gives a golden yellow flame.

17 a) Blue

b) i) Lead(II) chloride

ii) \( \text{Pb}^{2+}(\text{aq}) + 2\text{Cl}^- (\text{aq}) \rightarrow \text{PbCl}_2(\text{s}) \)

c) \( \text{CuCO}_3(\text{s}) / \text{MgCO}_3(\text{s}) + 2\text{H}^+ (\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) / \text{Mg}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g}) \)

d) A pale blue precipitate forms.

\( \text{Mg}^{2+}(\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow \text{Mg(OH)}_2(\text{s}) \)

white precipitate

\( \text{Cu}^{2+}(\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow \text{Cu(OH)}_2(\text{s}) \)

pale blue precipitate

Copper(II) hydroxide dissolves in excess NH\(_3\)(aq) to give a deep blue solution. The white precipitate remains.

\( \text{Cu(OH)}_2(\text{s}) + 4\text{NH}_3(\text{aq}) \rightarrow [\text{Cu(NH}_3)_4]^{2+}(\text{aq}) + 2\text{OH}^- (\text{aq}) \)

e) Sodium ion

18 A — H\(_2\)SO\(_4\)(aq)

B — Na\(_2\)SO\(_3\)(aq)

C — NaOH(aq)

D — BaCl\(_2\)(aq)

E — Fe(NO\(_3\))\(_2\)(aq)

F — NaOCl(aq)

A and B gives a gas that turns aqueous solution of potassium dichromate green (sulphur dioxide). Thus, A and B should be H\(_2\)SO\(_4\)(aq) and Na\(_2\)SO\(_3\)(aq).

\( \text{SO}_3^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow \text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \)

A and F give a gas that turns moist blue litmus paper red and then bleaches it (chlorine). Thus, A and F should be H\(_2\)SO\(_4\)(aq) and NaOCl(aq).

\( \text{OCl}^- (\text{aq}) + 2\text{H}^+(\text{aq}) + \text{Cl}^- (\text{aq}) \rightarrow \text{Cl}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \)

Hence it can be deduced that A is H\(_2\)SO\(_4\)(aq), B is Na\(_2\)SO\(_3\)(aq) and F is NaOCl(aq).

A and D give a white precipitate. Thus, D is BaCl\(_2\)(aq). It gives BaSO\(_4\)(s) with A (H\(_2\)SO\(_4\)(aq)).
Ba\(^{2+}\)(aq) + SO\(_{4}\)\(^{2-}\)(aq) → BaSO\(_{4}\)(s)

Hence D is BaCl\(_{2}\)(aq).

C and E give a white precipitate. Thus, C and E should be NaOH(aq) and Fe(NO\(_{3}\))\(_{2}\)(aq).

Fe\(^{2+}\)(aq) + 2OH\(^{-}\)(aq) → Fe(OH)\(_{2}\)(s)

When C is mixed with A, only heat is liberated. Thus, it can be deduced that a neutralization occurs.

H\(^{+}\)(aq) + OH\(^{-}\)(aq) → H\(_{2}\)O(l)

Hence C is NaOH(aq) and E is Fe(NO\(_{3}\))\(_{2}\)(aq).

19 The anions can be classified into two groups:
- Br\(^{-}\)(aq) ion forms insoluble silver salts;
- CO\(_{3}\)\(^{2-}\)(aq) ion and SO\(_{4}\)\(^{2-}\)(aq) ion form insoluble barium salts. They can be precipitated from a solution by adding aqueous solution of barium nitrate.

Barium carbonate is soluble in dilute hydrochloric acid while barium sulphate is not.

BaCO\(_{3}\)(s) + 2H\(^{+}\)(aq) → Ba\(^{2+}\)(aq) + CO\(_{2}\)(g) + H\(_{2}\)O(l)
<table>
<thead>
<tr>
<th>Test</th>
<th>Observation</th>
<th>Deduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smelling / warming some solution in a test tube</td>
<td>characteristic smell of ammonia</td>
<td>The tube contains NH₃(aq).</td>
</tr>
<tr>
<td>Add NH₃(aq) to give test tubes containing the other five solutions</td>
<td>one of the solutions forms a brown precipitate that dissolves in excess NH₃(aq) to give a colourless solution</td>
<td>The tube contains AgNO₃(aq).</td>
</tr>
<tr>
<td></td>
<td>two of the solutions form white precipitates that dissolve in excess NH₃(aq) to give colourless solutions</td>
<td>The tubes contain ZnSO₄(aq) and ZnCl₂(aq).</td>
</tr>
<tr>
<td>Add AgNO₃(aq) to four test tubes containing solutions other than NH₃(aq)</td>
<td>two of the solutions form white precipitates</td>
<td>The tubes contain HCl(aq) and ZnCl₂(aq). Hence the solution that gives observable changes with both NH₃(aq) and AgNO₃(aq) is ZnCl₂(aq). The solution that gives observable changes with NH₃(aq) only is ZnSO₄(aq). The solution that gives observable changes with AgNO₃(aq) only is HCl(aq). The remaining solution is Na₂SO₄(aq).</td>
</tr>
</tbody>
</table>

21 **Divide the samples into two groups: sodium compounds and ammonium compounds**

Conduct a flame test using the samples.

Only the three sodium compounds give a golden yellow flame.

**OR**

Warm the samples with NaOH(aq).

Only the two ammonium compounds give a gas that turns moist red litmus paper blue (ammonia).

**Distinguish between the sodium compounds**

Add HCl(aq) to the three sodium compounds.

Sodium carbonate gives a colourless gas that turns limewater milky (carbon dioxide).

Sodium hypochlorite gives a gas that turns moist blue litmus paper red and then bleaches it
(chlorine).
Hence the remaining sample is sodium chloride.

**Distinguish between the ammonium compounds**
Add acidified BaCl$_2$(aq) to the aqueous solution of the two ammonium compounds. Only the aqueous solution of ammonium sulphate gives a white precipitate (BaSO$_4$(s)).