# Mastering Chemistry

- Book 2A
- Topic 4 Acids and Bases

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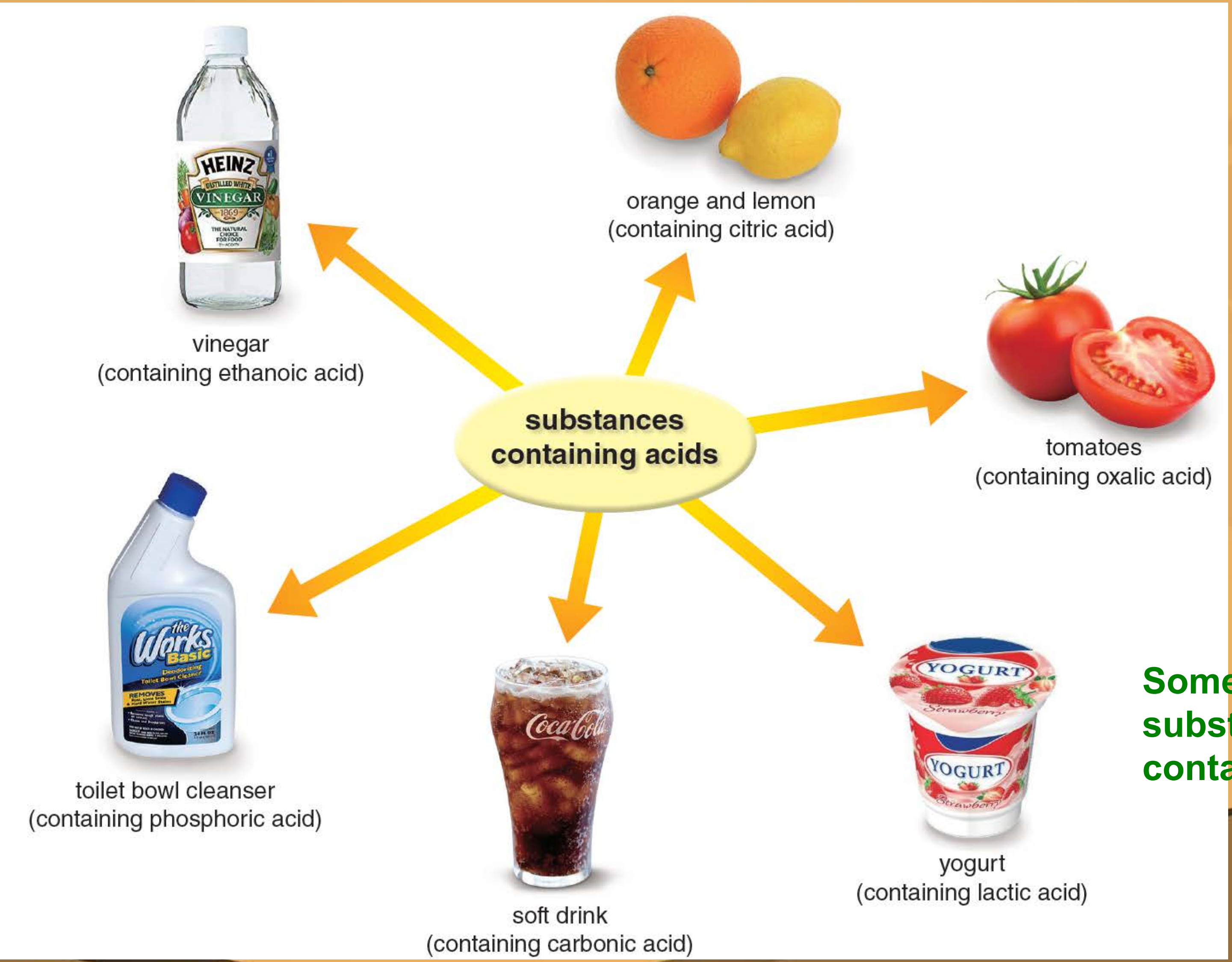
# Content

# 14.1 Acids around you (p.2)

- Vinegar contains **ethanoic acid (乙酸)**. Orange, lemon and other citrus fruits contain **citric acid (檸檬酸)**. Tomato contains **oxalic acid (草酸)**. Yogurt contains **lactic acid (乳酸)**. They are all sour tasting because of the presence of acids.
- **Carbonic acid (碳酸)** from carbon dioxide dissolved in water is present in soft drinks. Some toilet bowl and tile cleansers contain **phosphoric acid (磷酸)**.

# 14.1 Acids around you (p.2)




**Some common substances that contain acids**

# 14.2 Characteristics of dilute acids (p.3)

- Three acids commonly found in the laboratory are
  - dilute **hydrochloric acid (氫氯酸)**(HCl(aq));
  - dilute **sulphuric acid (硫酸)** ($H_2SO_4$(aq));
  - dilute **nitric acid (硝酸)** ($HNO_3$(aq)).


**Common acids found in the laboratory: dilute hydrochloric acid, dilute sulphuric acid and dilute nitric acid (from left to right)**

**Investigating the properties of dilute hydrochloric acid *Ref.***

# 14.2 Characteristics of dilute acids (p.3)

- These are called **mineral acids (礦酸)** because they are derived from minerals.
- Dilute acids
  - are conductors of electricity;
  - react with reactive metals;
  - react with bases;
  - react with metal carbonates and hydrogencarbonates.

# 14.2 Characteristics of dilute acids (p.3)

## Electrical conductivity

- Dilute hydrochloric acid and dilute sulphuric acid conduct electricity because they contain mobile ions for carrying the current.


Experimental set-up to test the electrical conductivity of a dilute acid

# 14.2 Characteristics of dilute acids (p.3)

## Reaction with reactive metals

- Both dilute hydrochloric acid and dilute sulphuric acid can react with a metal above hydrogen in the reactivity series, forming hydrogen plus an ionic compound called a salt.

**metal + dilute acid → salt + hydrogen**

- The hydrogen present in the acid is replaced by a metal to give a salt. The salt formed depends upon the acid and the metal used. Hydrochloric acid gives salts called chlorides while sulphuric acid gives salts called sulphates.

# 14.2 Characteristics of dilute acids (p.3)

- For example, magnesium reacts with dilute hydrochloric acid, forming magnesium chloride and hydrogen.

$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

- The hydrogen is released as bubbles in the acid. Soluble magnesium chloride also forms. This is why a piece of magnesium ribbon appears to dissolve if you put it into dilute hydrochloric acid.
- Iron reacts with dilute sulphuric acid, forming iron(II) sulphate and hydrogen.

$$Fe(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2(g)$$

# 14.2 Characteristics of dilute acids (p.3)

- Unreactive metals, such as copper, do not react with both dilute hydrochloric acid and dilute sulphuric acid.

Magnesium ribbon reacting with dilute hydrochloric acid — giving off hydrogen

Iron reacting with dilute sulphuric acid — giving off hydrogen

# 14.2 Characteristics of dilute acids (p.3)

## Reaction with bases

- Most oxides and hydroxides of metals are **bases (鹽基)**. A base is a substance that reacts with an acid to form a salt and water only. This reaction is known as a **neutralisation (中和作用)**.

**oxide or hydroxide of metal + dilute acid $\longrightarrow$ salt + water**

# 14.2 Characteristics of dilute acids (p.3)

- Copper(II) oxide is insoluble in water. It reacts with dilute sulphuric acid to form copper(II) sulphate and water.

$$CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$$

**The reaction between copper(II) oxide and dilute sulphuric acid to form a blue copper(II) sulphate solution**

# 14.2 Characteristics of dilute acids (p.3)

- Zinc hydroxide is also insoluble in water. It reacts with dilute hydrochloric acid to form zinc chloride and water.

$$Zn(OH)_2(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + 2H_2O(l)$$

# 14.2 Characteristics of dilute acids (p.3)

## Reaction with metal carbonates and hydrogencarbonates

- Both dilute hydrochloric acid and dilute sulphuric acid react with a metal carbonate or hydrogencarbonate to form a salt, water and carbon dioxide.

**metal carbonate or hydrogencarbonate + dilute acid ⟶ salt + water + carbon dioxide**

# 14.2 Characteristics of dilute acids (p.3)

- Calcium carbonate reacts with dilute hydrochloric acid to form calcium chloride, water and carbon dioxide.

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

- The carbon dioxide is released as bubbles in the acid. **Effervescence (泡騰)** occurs.

**Calcium carbonate reacts with dilute hydrochloric acid to give carbon dioxide gas. Effervescence occurs as a result**

# 14.2 Characteristics of dilute acids (p.3)

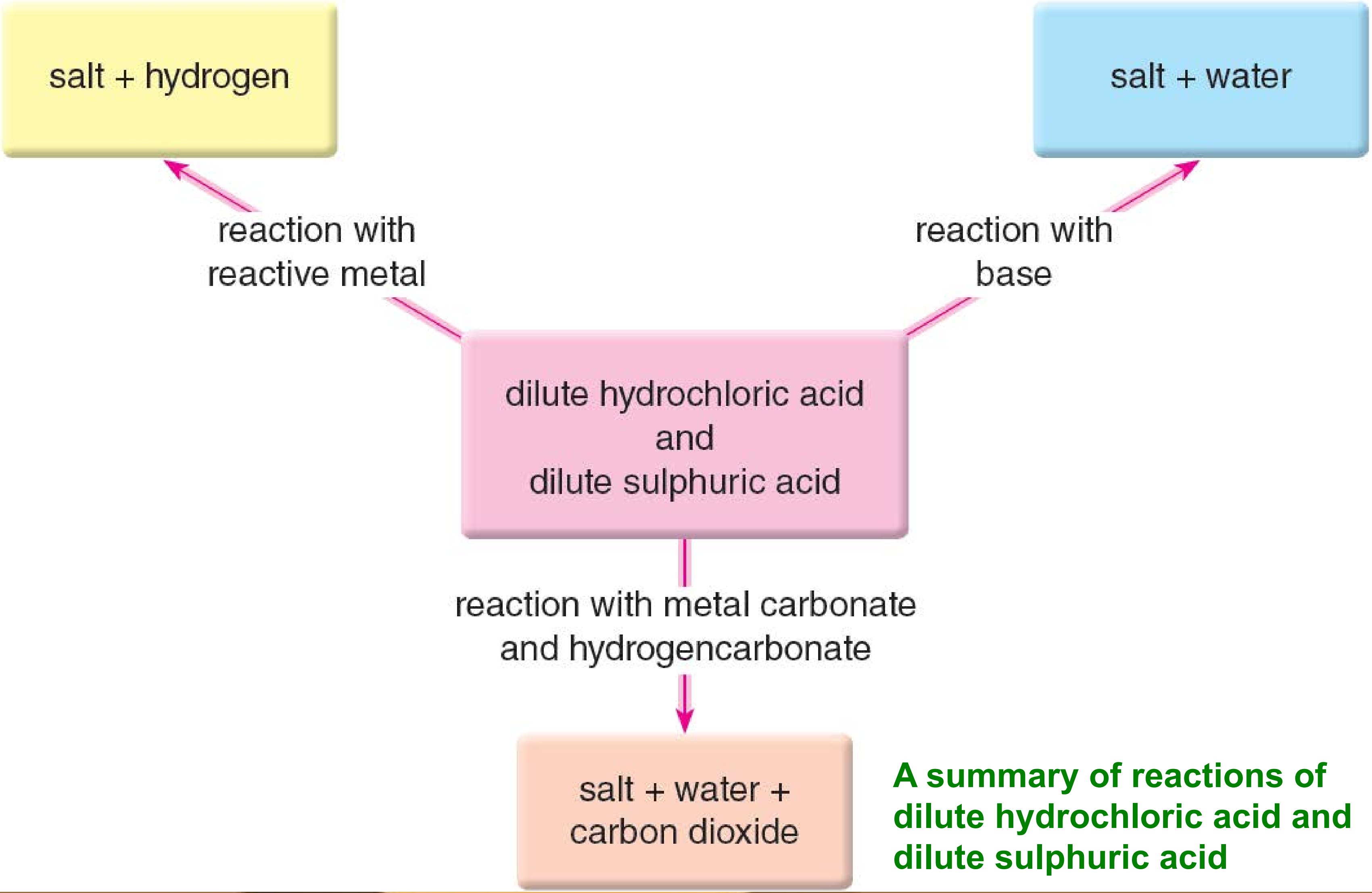
- The presence of carbon dioxide can be confirmed by bubbling the gas through limewater. The limewater initially turns milky, but then becomes clear again if excess carbon dioxide is passed through the limewater.

$$CO_2(g) + Ca(OH)_2(aq) \longrightarrow CaCO_3(s) + H_2O(l)$$
$$CaCO_3(s) + H_2O(l) + CO_2(g) \longrightarrow Ca(HCO_3)_2(aq)$$

- Sodium hydrogencarbonate (solid or solution) reacts with dilute sulphuric acid to form sodium sulphate, water and carbon dioxide.

$$2NaHCO_3(s\ or\ aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$$

# 14.2 Characteristics of dilute acids (p.3)




**A summary of reactions of dilute hydrochloric acid and dilute sulphuric acid**

# 14.2 Characteristics of dilute acids (p.3)

## Practice 14.1

1 a) State the products for each of the following reactions involving dilute hydrochloric acid.

i) iron + dilute hydrochloric acid $\longrightarrow$
iron(II) chloride + hydrogen

ii) limewater + dilute hydrochloric acid $\longrightarrow$
calcium chloride + water

iii) magnesium carbonate + dilute hydrochloric acid $\longrightarrow$
magnesium chloride + water + carbon dioxide

b) Write the chemical equation for each reaction in (a).

i) $Fe(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$

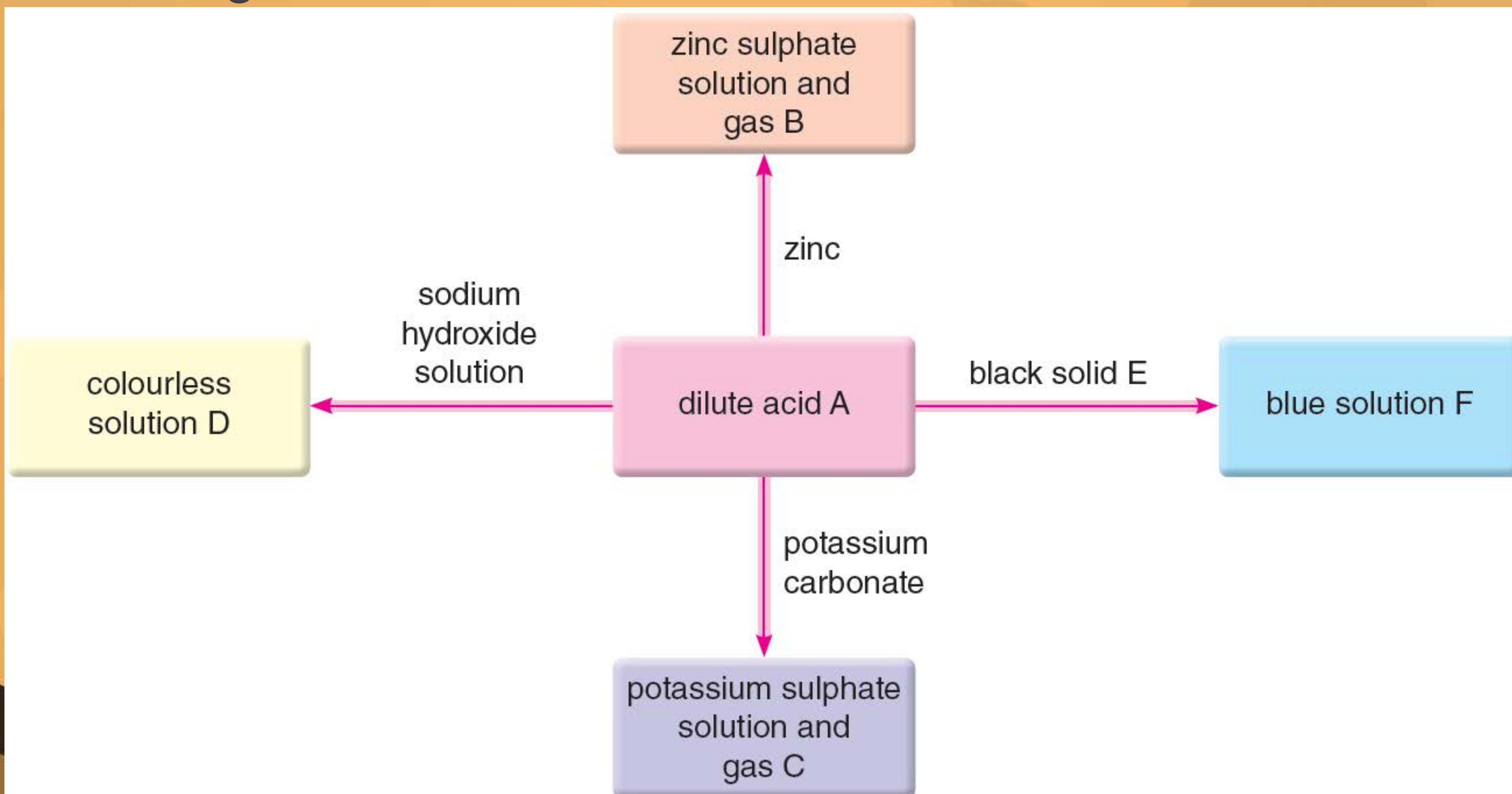
ii) $Ca(OH)_2(aq) + 2HCl(aq) \longrightarrow CaCl_2(aq) + 2H_2O(l)$

iii) $MgCO_3(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$

# 14.2 Characteristics of dilute acids (p.3)

## Practice 14.1 (continued)

2 The diagram below shows some reactions of a common.



# 14.2 Characteristics of dilute acids (p.3)

Practice 14.1 (continued)

2 a) Give the names of

i) acid A; dilute sulphuric acid

ii) gas B; hydrogen

iii) gas C; carbon dioxide

iv) colourless solution D; sodium sulphate solution

v) black solid E; copper(II) oxide

vi) blue solution F. copper(II) sulphate solution

b) Suggest a test for identifying gas B.

Test with a burning splint.

Gas B gives a ‘pop’ sound.

# 14.3 The role of water in exhibiting properties of acid (p.9)

- Pure acids may be solids (such as citric acid and oxalic), liquids (such as sulphuric acid, nitric acid and ethanoic acid) or gases (such as hydrogen chloride which becomes hydrochloric acid when it dissolves in water).


**Citric acid crystals and oxalic acid crystals**

**Comparing the properties of solid citric acid and its aqueous solution *Ref.***

# 14.3 The role of water in exhibiting properties of acid (p.9)

- Test citric acid crystals and the aqueous solution of citric acid with
  - dry blue litmus paper;
  - magnesium ribbon;
  - sodium carbonate.
- Only the aqueous solution of citric acid exhibits typical properties of an acid. This suggests that water must be present for an acid to exhibit its typical properties.

| Test | Citric acid crystals | Aqueous solution of citric acid |
|---|---|---|
| Dry blue litmus paper | remains blue | turns red |
| Magnesium ribbon | no reaction | colourless gas bubbles form (hydrogen gas is given off) |
| Sodium carbonate | no reaction | colourless gas bubbles form (carbon dioxide gas is given off) |

# 14.3 The role of water in exhibiting properties of acid (p.9)

- When citric acid crystals dissolve in water, the citric acid molecules dissociate (or ionise) to produce hydrogen ions. This process is called **dissociation (離解作用)**.

citric acid + water ⟶ hydrogen ion + citrate ion

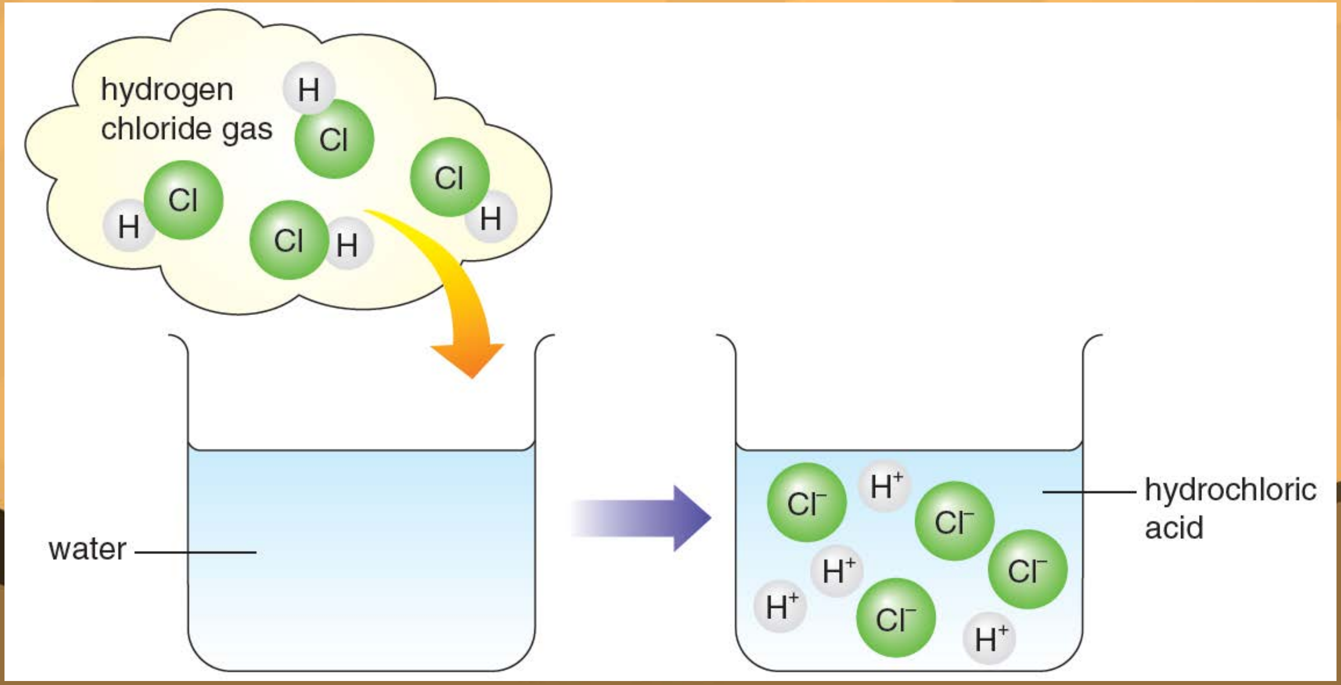
- It is the hydrogen ions that are responsible for the typical properties of an acid.

# 14.3 The role of water in exhibiting properties of acid (p.9)

Dissolving hydrogen chloride in water *Ref.*

- Consider another example. When hydrogen chloride gas dissolves in water, the hydrogen chloride molecules dissociate to produce hydrogen ions.

$$HCl(g) + water \longrightarrow H^{+}(aq) + Cl^{-}(aq)$$




**The HCl molecules dissociate in water to form ions**

# 14.3 The role of water in exhibiting properties of acid (p.9)

- In a similar way, molecules of sulphuric acid and nitric acid dissociate to produce hydrogen ions in water.

$$H_2SO_4(l) + \text{water} \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

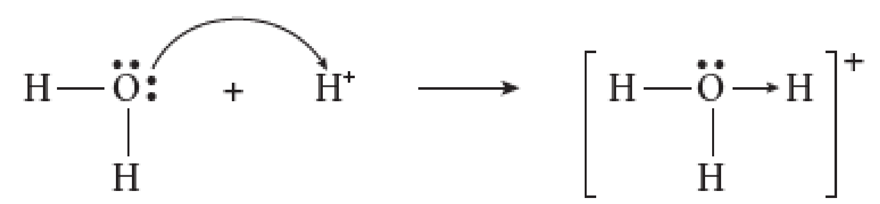
$$HNO_3(l) + \text{water} \longrightarrow H^+(aq) + NO_3^-(aq)$$

**An acid is a compound which produces hydrogen ions ($H^+(aq)$) as the only positive ions when dissolved in water.**

# 14.3 The role of water in exhibiting properties of acid (p.9)

## Hydrogen ion in aqueous solution

- An acid produces hydrogen ions when dissolved in water. A hydrogen atom loses its only electron to form a hydrogen ion which is simply a proton.
- A hydrogen ion is too reactive to exist by itself in an aqueous solution. It combines with a water molecule via a dative covalent bond, producing a **hydroxonium ion (水合氫離子)** (or hydronium ion), $H_3O^+$.



- For convenience, $H^+(aq)$ is used instead of $H_3O^+(aq)$ to represent a hydrogen ion in an aqueous solution.

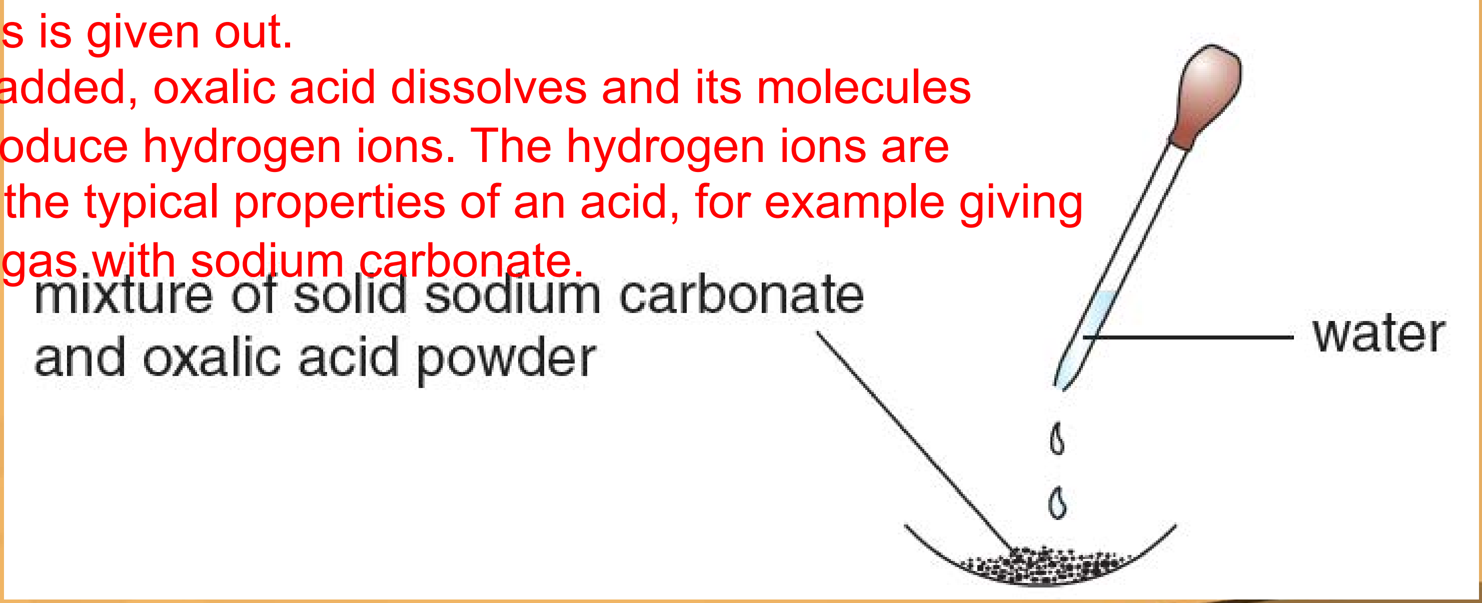
# 14.3 The role of water in exhibiting properties of acid (p.9)

## Practice 14.2

A student mixed solid sodium carbonate with oxalic acid powder. He then added water to the mixture.

A colourless gas is given out.

When water is added, oxalic acid dissolves and its molecules dissociate to produce hydrogen ions. The hydrogen ions are responsible for the typical properties of an acid, for example giving carbon dioxide gas with sodium carbonate.




What would you expect to observe? Explain.

# 14.4 Ionic equations for reactions of dilute acids (p.12)

- All acids produce hydrogen ions when dissolved in water and this is why dilute acids all react in a similar way. The typical reactions of dilute acids are reactions of hydrogen ions.

**Reaction between magnesium and dilute hydrochloric acid**

- Refer to the chemical equation for the reaction between magnesium and dilute hydrochloric acid:
  $Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$
- Rewrite the equation to show the ions in the solution.
  $Mg(s) + 2H^+(aq) + 2Cl^-(aq) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq) + H_2(g)$
- The chloride ions do not take part in the reaction. Hence they are left out of the equation. The ionic equation for the reaction is: $Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$

# 14.4 Ionic equations for reactions of dilute acids (p.12)

## Reaction between sodium hydrogencarbonate solution and dilute sulphuric acid

- Refer to the chemical equation for the reaction between sodium hydrogencarbonate solution and dilute sulphuric acid:

$$2NaHCO_3(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$$

- Rewrite the equation to show the ions in the solution.

$$2Na^+(aq) + 2HCO_3^-(aq) + 2H^+(aq) + SO_4^{2-}(aq) \longrightarrow 2Na^+(aq) + SO_4^{2-}(aq) + 2H_2O(l) + 2CO_2(g)$$

# 14.4 Ionic equations for reactions of dilute acids (p.12)

- Leaving out the sodium ions and sulphate ions that do not take part in the reaction, the equation becomes:
  $2HCO_3^-(aq) + 2H^+(aq) \longrightarrow 2H_2O(l) + 2CO_2(g)$
- Simplify to give the ionic equation below:
  $HCO_3^-(aq) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g)$

# 14.4 Ionic equations for reactions of dilute acids (p.12)

Practice 14.3

1 Transcribe the following chemical equations into ionic equations.

a) $Fe(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2(g)$

$Fe(s) + 2H^+(aq) \longrightarrow Fe^{2+}(aq) + H_2(g)$

b) $CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

$CaCO_3(s) + 2H^+(aq) \longrightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$

2 Effervescence occurs when a few drops of lemon juice are added to sodium carbonate powder.

Write the ionic equation for the reaction involved.

$Na_2CO_3(s) + 2H^+(aq) \longrightarrow 2Na^+(aq) + H_2O(l) + CO_2(g)$

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

# 14.5 Basicity of an acid (p.13)

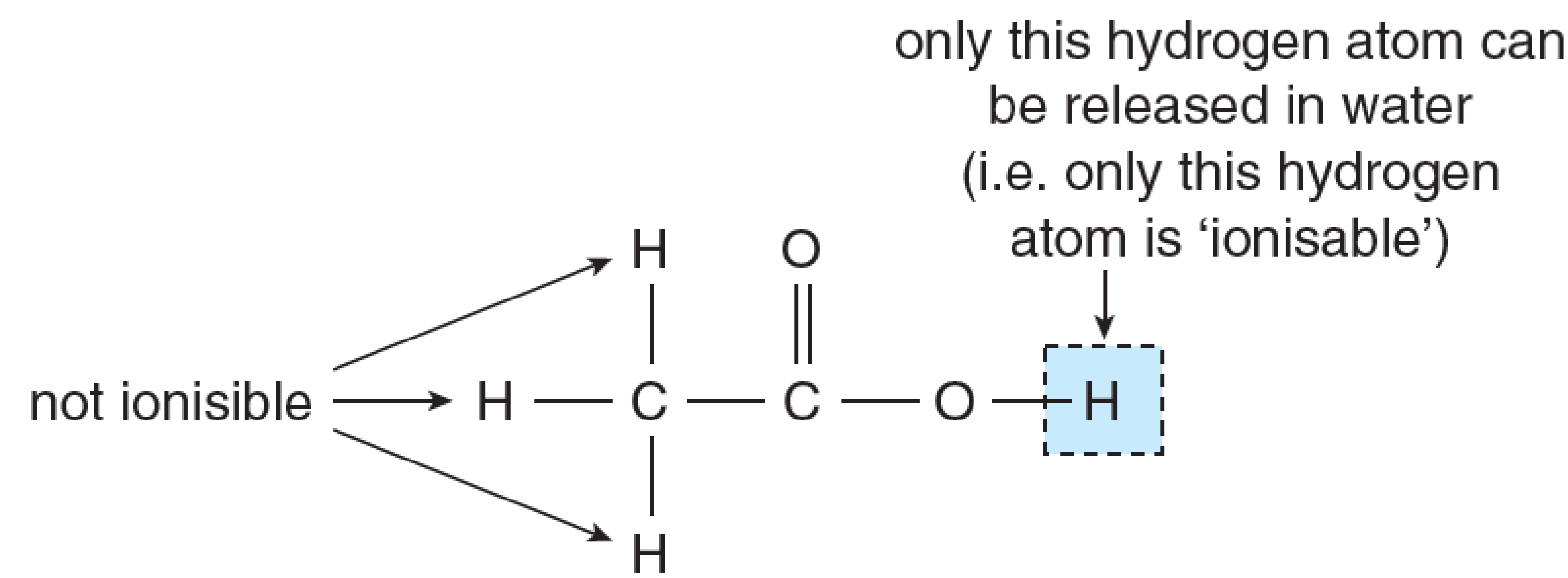
**The basicity (鹽基度) of an acid is the maximum number of hydrogen ions that can be produced by one molecule of the acid.**

- Hydrochloric acid is a **monobasic acid (一元酸)** because every hydrogen chloride molecule produces one hydrogen ion in water.

$$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$$

# 14.5 Basicity of an acid (p.13)

- Ethanoic acid ($CH_3COOH$) shown below is also a monobasic acid. In a molecule of the acid, only the hydrogen atom bonded to the –COO group can be released as a hydrogen ion in water.




**Ethanoic acid is a monobasic acid because only the hydrogen atom bonded to the –COO group can be released as a hydrogen ion in water**

# 14.5 Basicity of an acid (p.13)

- Sulphuric acid is a **dibasic acid (二元酸)**. When the acid is mixed with water, each molecule dissociates to give one hydrogen ion first.

$$H_2SO_4(aq) \longrightarrow H^+(aq) + HSO_4^-(aq)$$

- The resulting $HSO_4^-(aq)$ ions then only partially dissociate:

$$HSO_4^-(aq) \rightleftharpoons H^+(aq) + SO_4^{2-}(aq)$$

- Phosphoric acid ($H_3PO_4(aq)$) is a **tribasic acid (三元酸)**. Its dissociations are described by the equations below.

$$H_3PO_4(aq) \rightleftharpoons H^+(aq) + H_2PO_4^-(aq)$$

$$H_2PO_4^-(aq) \rightleftharpoons H^+(aq) + HPO_4^{2-}(aq)$$

$$HPO_42–(aq) \rightleftharpoons H^+(aq) + PO_4^{3-}(aq)$$

# 14.5 Basicity of an acid (p.13)

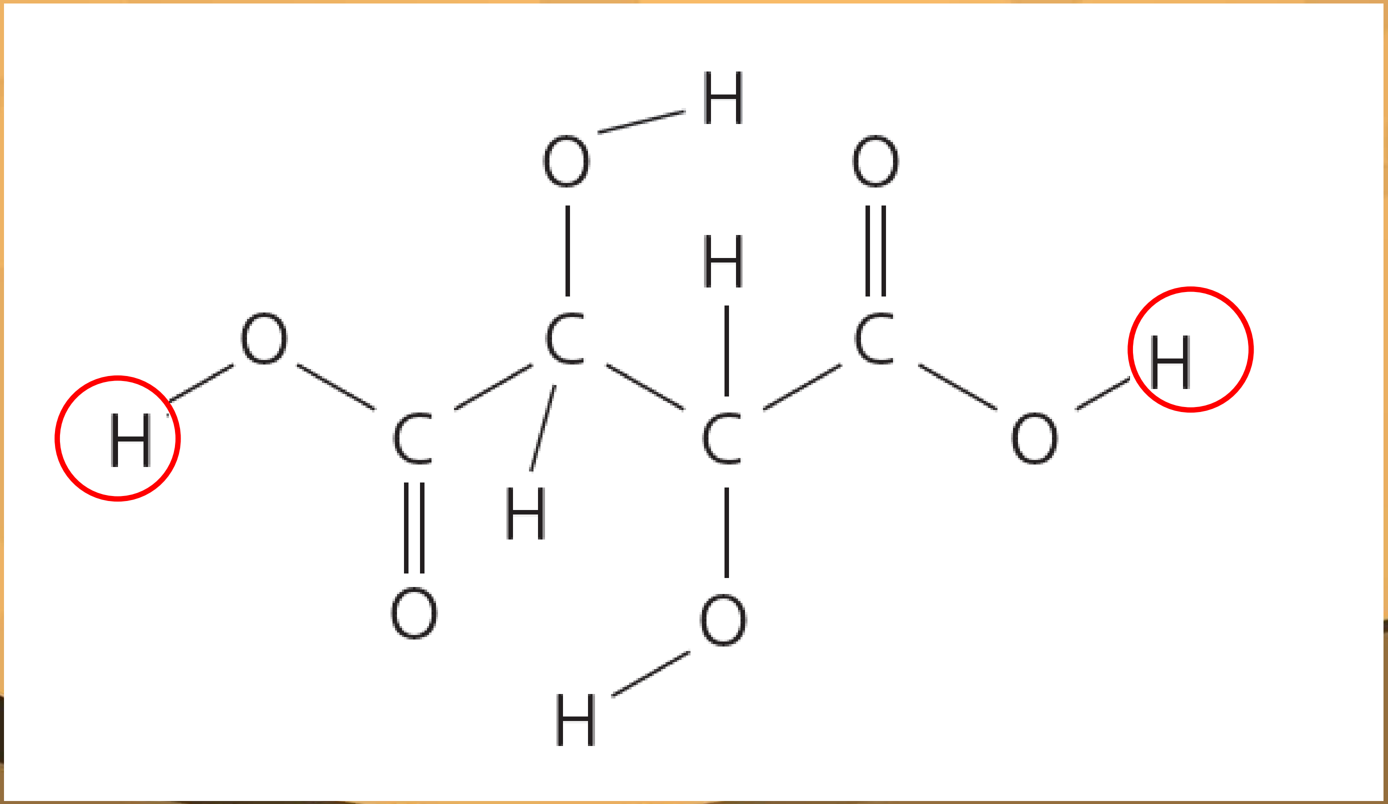
- The table below summarises the basicity of some common acids. The hydrogen atom(s) that can be released as ion(s) in water by one molecule of each acid is / are shown in red.

| Name of acid | Chemical formula | Basicity |
|---|---|---|
| Hydrochloric acid | $HCl$ | 1 |
| Nitric acid | $HNO_3$ | 1 |
| Ethanoic acid | $CH_3COOH$ | 1 |
| Carbonic acid | $H_2CO_3$ | 2 |
| Sulphuric acid | $H_2SO_4$ | 2 |
| Phosphoric acid | $H_3PO_4$ | 3 |

# 14.5 Basicity of an acid (p.13)

## Practice 14.4

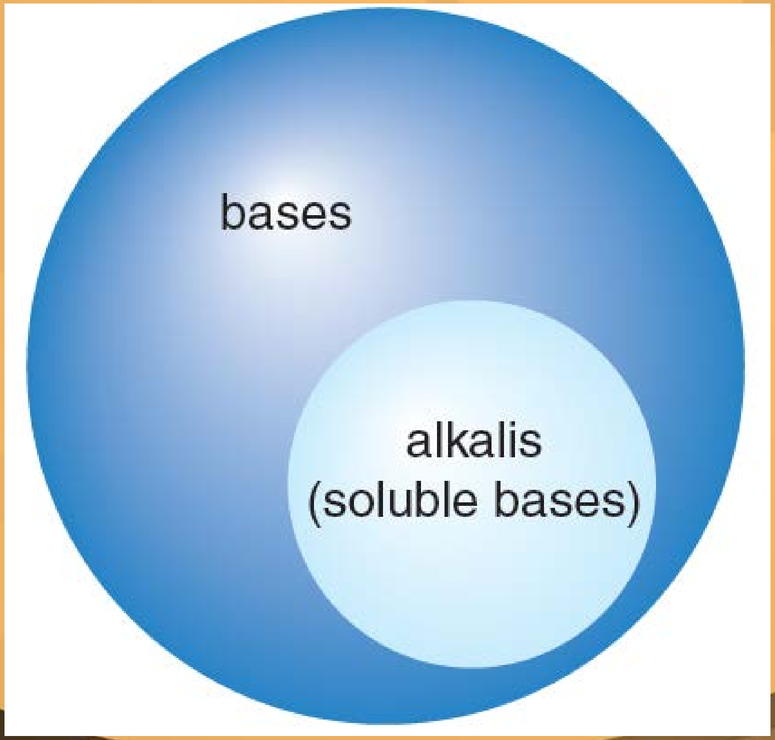
The structure of tartaric acid is shown below. It is a dibasic acid. Identify all the ionisable hydrogen atoms.



# 14.6 Bases and alkalis (p.15)

- Most oxides and hydroxides of metals are bases. A base is a substance that neutralises an acid to form a salt and water only.
- **Alkalis (鹼)** are bases which are soluble in water.




The relationship between bases and alkalis

# 14.6 Bases and alkalis (p.15)

- The table below lists examples of insoluble bases and soluble bases (alkalis).

| Insoluble base | Soluble base (alkali) |
|---|---|
| copper(II) oxide ($CuO$) | sodium hydroxide ($NaOH$) |
| magnesium oxide ($MgO$) | potassium hydroxide ($KOH$) |
| lead(II) oxide ($PbO$) | calcium hydroxide ($Ca(OH)_2$) |
| iron(III) hydroxide ($Fe(OH)_3$) | ammonia ($NH_3$) |

# 14.6 Bases and alkalis (p.15)

- Sodium hydroxide is an alkali. It is an ionic solid. When it dissolves in water, the crystal lattice is broken down and the ions spread throughout the solution.

$$NaOH(s) + water \longrightarrow Na^{+}(aq) + OH^{-}(aq)$$

- When ammonia gas dissolves in water, some of the ammonia molecules react with water molecules. Hydroxide ions are produced in this reaction.

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

- Ammonia is therefore an alkali. However, ammonia does not react with water completely. Only a small amount of hydroxide ions are formed.

# 14.6 Bases and alkalis (p.15)

**An alkali is a base which releases hydroxide ions ($OH^-$(aq)) when dissolved in water.**

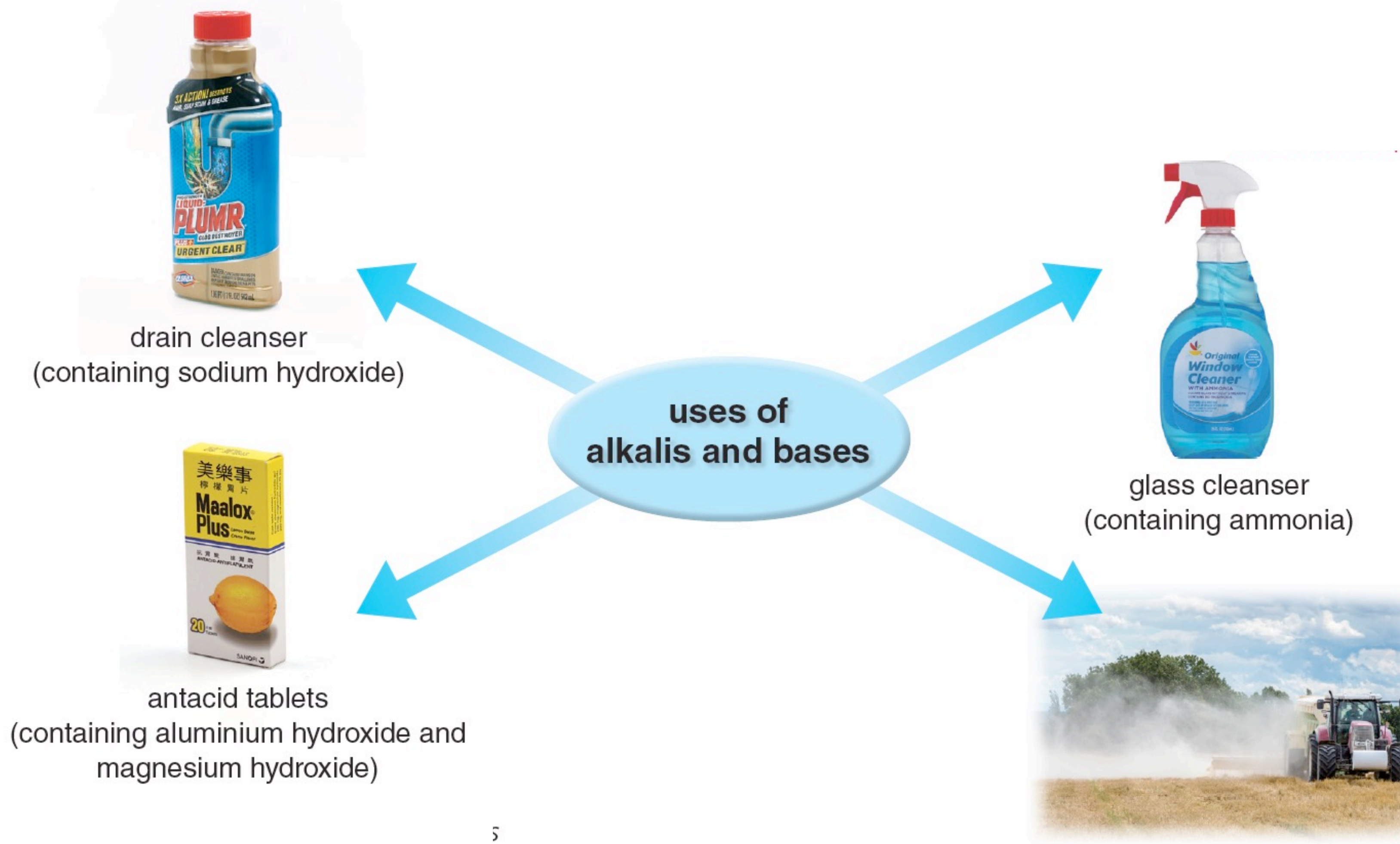
- The properties of solutions of alkalis depend on the presence of hydroxide ions ($OH^-$(aq)).

**Dissolving ammonia in water *Ref.***

# 14.7 Uses of alkalis and bases (p.16)

- Alkalis are used as degreasing agents because they convert oil and grease into soap which can be washed away easily.
- Many drain cleansers contain sodium hydroxide.
- Ammonia is present in many glass cleansers.
- Calcium hydroxide is used to reduce the acidity of soil.
- Aluminium hydroxide and magnesium hydroxide are used in antacid tablets.

# 14.7 Uses of alkalis and bases (p.16)




**Some common uses of alkalis and bases**

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

- Alkalis are usually used in the laboratory as dilute aqueous solutions. Four alkalis commonly found in the laboratory are
  - dilute **potassium hydroxide (氫氧化鉀)** solution, KOH(aq);
  - dilute **sodium hydroxide (氫氧化鈉)** solution, NaOH(aq);
  - **calcium hydroxide (氫氧化鈣)** solution, $Ca(OH)_2(aq)$;
  - dilute **aqueous ammonia (氨水)**, $NH_3(aq)$.


**Common alkalis found in the laboratory: dilute potassium hydroxide solution, dilute sodium hydroxide solution, calcium hydroxide solution and dilute aqueous ammonia (from left to right)**

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

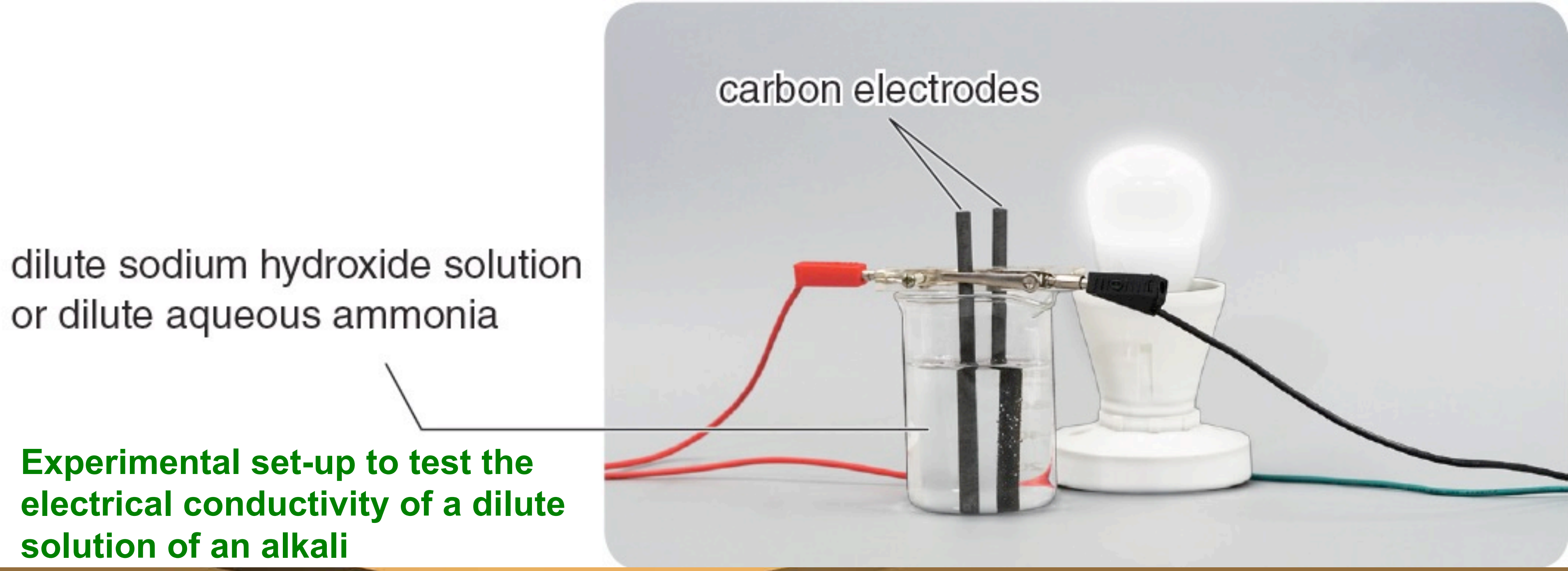
- Dilute solutions of alkalis feel slippery to the skin (they convert oils in the skin into soap) and have a bitter taste.
- Dilute solutions of alkalis
  - are conductors of electricity;
  - react with solutions containing certain metal ions to form precipitates;
  - react with ammonium compounds.

**Investigating the properties of dilute solutions of alkalis** ***Ref.***

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

## Electrical conductivity

- Dilute sodium hydroxide solution or dilute aqueous ammonia conduct electricity because they contain mobile ions for carrying the current.




**Experimental set-up to test the electrical conductivity of a dilute solution of an alkali**

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

## Reaction of dilute sodium hydroxide solution with solutions containing metal ions

- Most metal hydroxides are insoluble. The table below lists the results when dilute sodium hydroxide solution is added until in excess to solutions containing certain metal ions.

| Solution containing | On addition of a few drops of dilute NaOH(aq) | Chemical formula of precipitate formed | On addition of excess dilute NaOH(aq) |
|---|---|---|---|
| $Ca^{2+}(aq)$ | a white precipitate forms | $Ca(OH)_2$ | the precipitate does not dissolve |
| $Mg^{2+}(aq)$ | a white precipitate forms | $Mg(OH)_2$ | |
| $Al^{3+}(aq)$ | a white precipitate forms | $Al(OH)_3$ | the precipitate dissolves to give a colourless solution |
| $Pb^{2+}(aq)$ | a white precipitate forms | $Pb(OH)_2$ | |
| $Zn^{2+}(aq)$ | a white precipitate forms | $Zn(OH)_2$ | |
| $Fe^{2+}(aq)$ | a green precipitate forms | $Fe(OH)_2$ | the precipitate does not dissolve |
| $Fe^{3+}(aq)$ | a reddish brown precipitate forms | $Fe(OH)_3$ | |
| $Cu^{2+}(aq)$ | a pale blue precipitate forms | $Cu(OH)_2$ | |

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

- Magnesium sulphate solution reacts with dilute sodium hydroxide solution, forming a white precipitate of magnesium hydroxide.

  $MgSO_4(aq) + 2NaOH(aq) \longrightarrow Mg(OH)_2(s) + Na_2SO_4(aq)$

- This reaction can also be represented by the ionic equation below.

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

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

- Lead(II) nitrate solution reacts with dilute sodium hydroxide solution, forming a white precipitate of lead(II) hydroxide.

- The precipitate dissolves in excess dilute sodium hydroxide solution due to the formation of a soluble complex salt. A colourless solution is formed as a result.

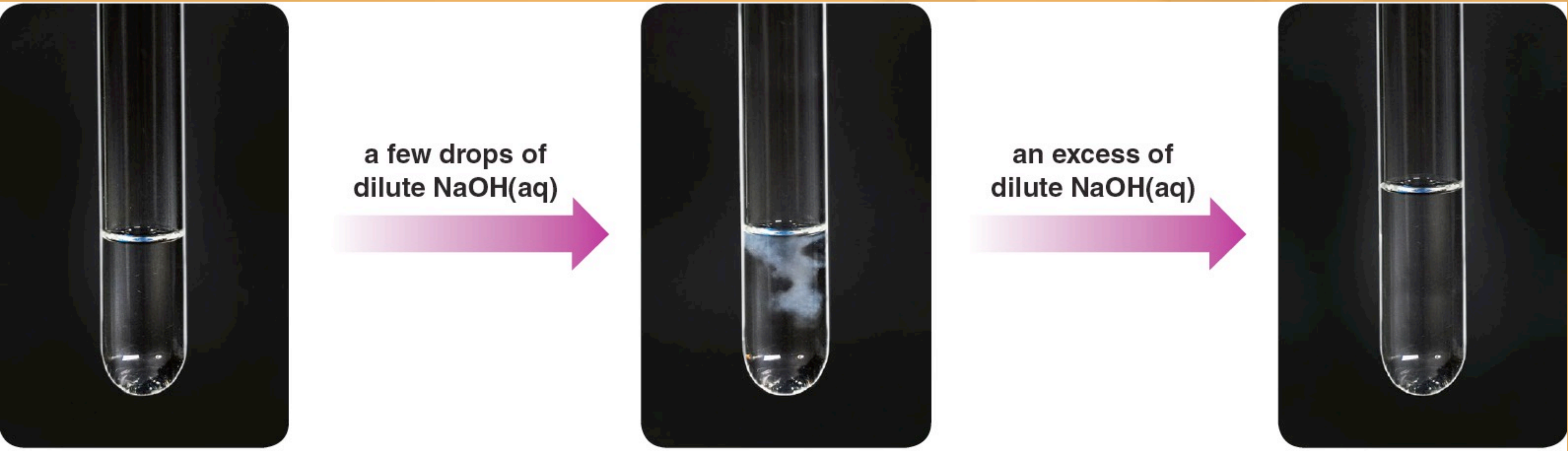
$$Pb^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Pb(OH)_2(s)$$

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

tetrahydroxoplumbate(II) ion

- Aluminium hydroxide and zinc hydroxide also dissolve in excess dilute sodium hydroxide solution due to the formation of soluble complex salts.

# 14.8 Characteristics of dilute solutions of alkalis (p.17)




solution containing lead(II) ions — lead(II) hydroxide precipitate — a colourless solution formed

**Lead(II) nitrate solution reacts with dilute sodium hydroxide solution to form a white precipitate; the precipitate dissolves in excess dilute sodium hydroxide solution to give a colourless solution**

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

- Ionic equations for reactions of solutions containing metal ions with dilute sodium hydroxide.

| Solution containing | Ionic equation(s) for reaction(s) with dilute NaOH(aq) |
|---|---|
| $Ca^{2+}(aq)$ | $Ca^{2+}(aq) + 2OH^-(aq) \longrightarrow Ca(OH)_2(s)$ |
| $Mg^{2+}(aq)$ | $Mg^{2+}(aq) + 2OH^-(aq) \longrightarrow Mg(OH)_2(s)$ |
| $Al^{3+}(aq)$ | $Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$<br>$Al(OH)_3(s) + OH^-(aq) \longrightarrow [Al(OH)_4]^-(aq)$<br>tetrahydroxoaluminate ion |
| $Pb^{2+}(aq)$ | $Pb^{2+}(aq) + 2OH^-(aq) \longrightarrow Pb(OH)_2(s)$<br>$Pb(OH)_2(s) + 2OH^-(aq) \longrightarrow [Pb(OH)_4]^{2-}(aq)$<br>tetrahydroxoplumbate(II) ion |
| $Zn^{2+}(aq)$ | $Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$<br>$Zn(OH)_2(s) + 2OH^-(aq) \longrightarrow [Zn(OH)_4]^{2-}(aq)$<br>tetrahydroxozincate ion |
| $Fe^{2+}(aq)$ | $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$ |
| $Fe^{3+}(aq)$ | $Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$ |
| $Cu^{2+}(aq)$ | $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$ |

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

## Reaction of dilute aqueous ammonia with solutions containing metal ions

- Solutions containing certain metal ions also form hydroxide precipitates with dilute aqueous ammonia.

| Solution containing | On addition of a few drops of dilute $NH_3(aq)$ | Chemical formula of precipitate formed | On addition of excess dilute $NH_3(aq)$ |
|---|---|---|---|
| $Mg^{2+}(aq)$ | a white precipitate forms | $Mg(OH)_2$ | the precipitate does not dissolve |
| $Al^{3+}(aq)$ | a white precipitate forms | $Al(OH)_3$ | |
| $Pb^{2+}(aq)$ | a white precipitate forms | $Pb(OH)_2$ | |
| $Zn^{2+}(aq)$ | a white precipitate forms | $Zn(OH)_2$ | the precipitate dissolves to give a colourless solution |
| $Fe^{2+}(aq)$ | a green precipitate forms | $Fe(OH)_2$ | the precipitate does not dissolve |
| $Fe^{3+}(aq)$ | a reddish brown precipitate forms | $Fe(OH)_3$ | |
| $Cu^{2+}(aq)$ | a pale blue precipitate forms | $Cu(OH)_2$ | the precipitate dissolves to give a deep blue solution |

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

- A solution of copper(II) ions reacts with dilute aqueous ammonia to form a pale blue precipitate of copper(II) hydroxide.

- The precipitate dissolves in excess dilute aqueous ammonia due to the formation of a soluble complex salt.

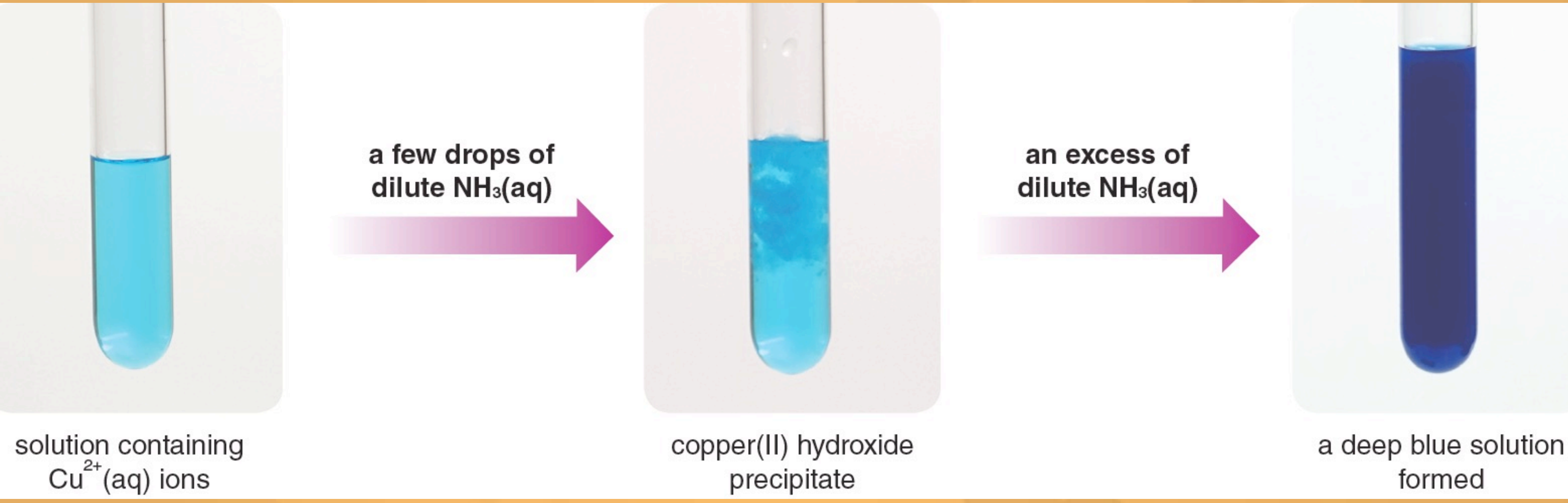
$$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$$

$$Cu(OH)_2(s) + 4NH_3(aq) \longrightarrow [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$$

tetraamminecopper(II) ion

- Zinc hydroxide also dissolves in excess dilute aqueous ammonia due to the formation of a soluble complex salt.

# 14.8 Characteristics of dilute solutions of alkalis (p.17)




**A solution of copper(II) ions reacts with dilute aqueous ammonia to form a pale blue precipitate; the precipitate dissolves in excess dilute aqueous ammonia to give a deep blue solution**

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

- Ionic equations for reactions of solutions containing metal ions with dilute aqueous.

| Solution containing | Ionic equation(s) for reaction(s) with dilute $NH_3(aq)$ |
|---|---|
| $Mg^{2+}(aq)$ | $Mg^{2+}(aq) + 2OH^-(aq) \longrightarrow Mg(OH)_2(s)$ |
| $Al^{3+}(aq)$ | $Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$ |
| $Pb^{2+}(aq)$ | $Pb^{2+}(aq) + 2OH^-(aq) \longrightarrow Pb(OH)_2(s)$ |
| $Zn^{2+}(aq)$ | $Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$<br>$Zn(OH)_2(s) + 4NH_3(aq) \longrightarrow [Zn(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$<br>tetraamminezinc ion |
| $Fe^{2+}(aq)$ | $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$ |
| $Fe^{3+}(aq)$ | $Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$ |
| $Cu^{2+}(aq)$ | $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$<br>$Cu(OH)_2(s) + 4NH_3(aq) \longrightarrow [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$<br>tetraamminecopper(II) ion |

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

## Reaction of dilute sodium hydroxide solution with ammonium compounds

- Ammonium compounds (such as ammonium chloride, ammonium nitrate and ammonium sulphate) contain ammonium ions. Heating them with dilute sodium hydroxide solution produces ammonia gas.
- Heating ammonium nitrate (solid or solution) with dilute sodium hydroxide solution produces ammonia gas, sodium nitrate and water.

$$NH_4NO_3(s \text{ or } aq) + NaOH(aq) \xrightarrow{\text{heat}} NH_3(g) + NaNO_3(aq) + H_2O(l)$$

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

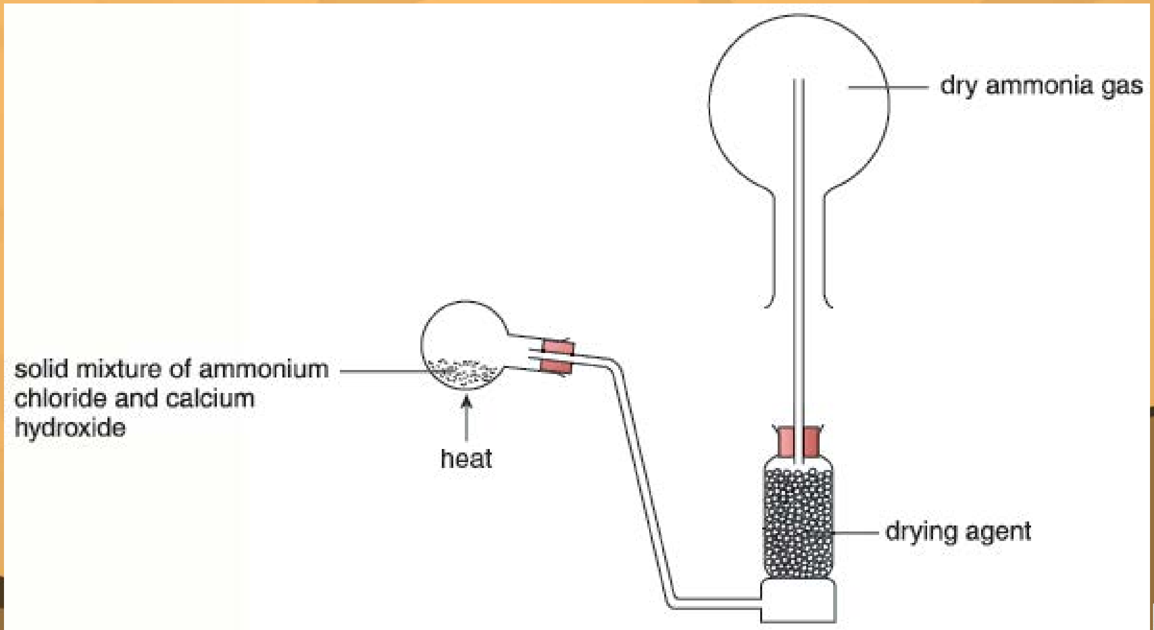
# 14.8 Characteristics of dilute solutions of alkalis (p.17)

## **Q** (Example 14.1)

A teacher carried an experiment to illustrate the solubility of ammonia gas in water. The experiment consisted of two parts.

Part I

A flask was filled with dry ammonia gas produced from the reaction between ammonium chloride and calcium hydroxide. The experimental set-up shown below was used.



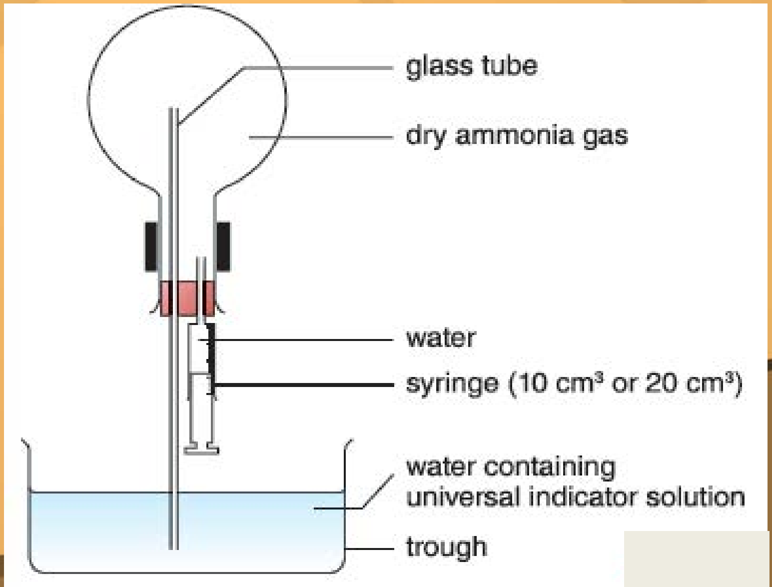

 

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

**Q** (Example 14.1) (continued)

Part II

The experimental set-up shown below was used. Several $cm^3$ of water were injected into the flask from the syringe. The water containing universal indicator solution was then automatically sucked into the flask through the glass tube.



# 14.8 Characteristics of dilute solutions of alkalis (p.17)

**Q** (Example 14.1) (continued)

a) Why was the ammonia gas collected by upward delivery in Part I?
b) Briefly explain why the water containing universal indicator solution was sucked into the flask.
c) State, with explanation, an observation related to the universal indicator in the flask.

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

**A**

a) Ammonia is less dense than air.

b) Ammonia is very soluble in water. As the gas dissolved, a partial vacuum formed and the atmospheric pressure would force the water in the trough to inject into the flask through the glass tube.

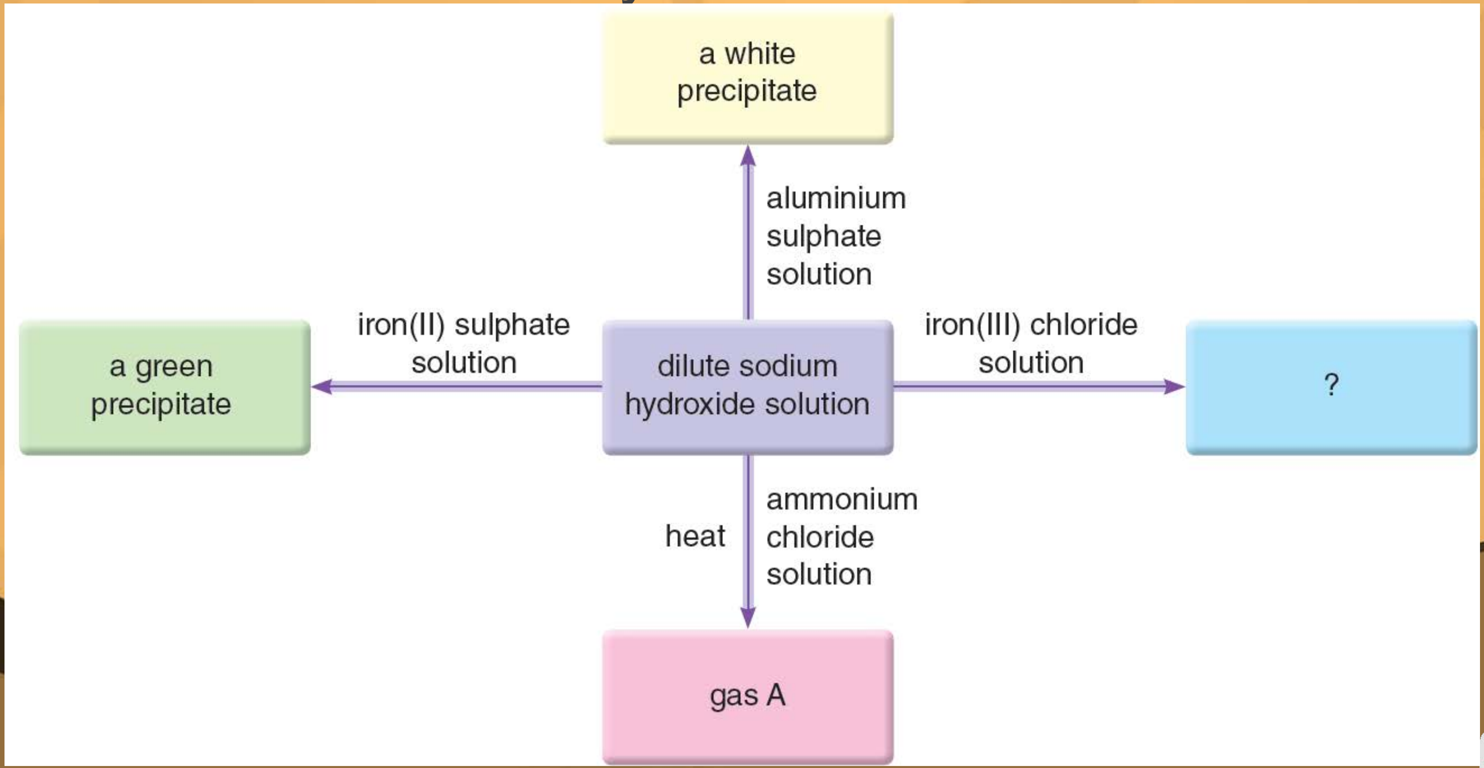
c) The water in flask turned from green to blue. This is because aqueous ammonia is alkaline.

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

## Practice 14.5

1 A student added dilute sodium hydroxide solution to four solutions containing metal or ammonium ions. The observations made by the student are shown below.



# 14.8 Characteristics of dilute solutions of alkalis (p.17)

Practice 14.5 (continued)

1 a) Give the chemical formula of the green precipitate formed from the reaction between iron(II) sulphate solution and dilute sodium hydroxide solution.

$Fe(OH)_2$

b) i) What would be observed when dilute sodium hydroxide solution was added to iron(III) chloride solution?

A reddish brown precipitate appears.

ii) Write the ionic equation for the reaction involved.

$$Fe^{3+}(aq) + 3OH^{-}(aq) \longrightarrow Fe(OH)_3(s)$$

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

## Practice 14.5 (continued)

1 c) i) Name the white precipitate formed from the reaction between aluminium sulphate solution and dilute sodium hydroxide solution.

Aluminium hydroxide

ii) The white precipitate dissolved in excess dilute sodium hydroxide solution to give a colourless solution.

Aluminium hydroxide dissolves in excess dilute sodium hydroxide solution due to the formation of a soluble complex salt.

Explain with the aid of an equation.

$Al(OH)_3(s) + OH^-(aq) \longrightarrow [Al(OH)_4]^-(aq)$

d) i) Name gas A. Ammonia

ii) Write the ionic equation for the reaction between ammonium chloride solution and dilute sodium hydroxide solution.

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

# 14.8 Characteristics of dilute solutions of alkalis (p.17)

Practice 14.5 (continued)

2 Solution of which alkali must be used to distinguish between a solution containing zinc ions and a solution containing lead(II) ions? What is the observation that distinguishes the two?

Dilute aqueous ammonia.

A solution containing zinc ions gives a white precipitate (zinc hydroxide) with dilute aqueous ammonia. The precipitate dissolves in excess dilute aqueous ammonia.

A solution containing lead(II) ions gives a white precipitate (lead(II) hydroxide) with dilute aqueous ammonia. The precipitate does not dissolve in excess dilute aqueous ammonia.

# 14.9 Concentrated acids (p.25)

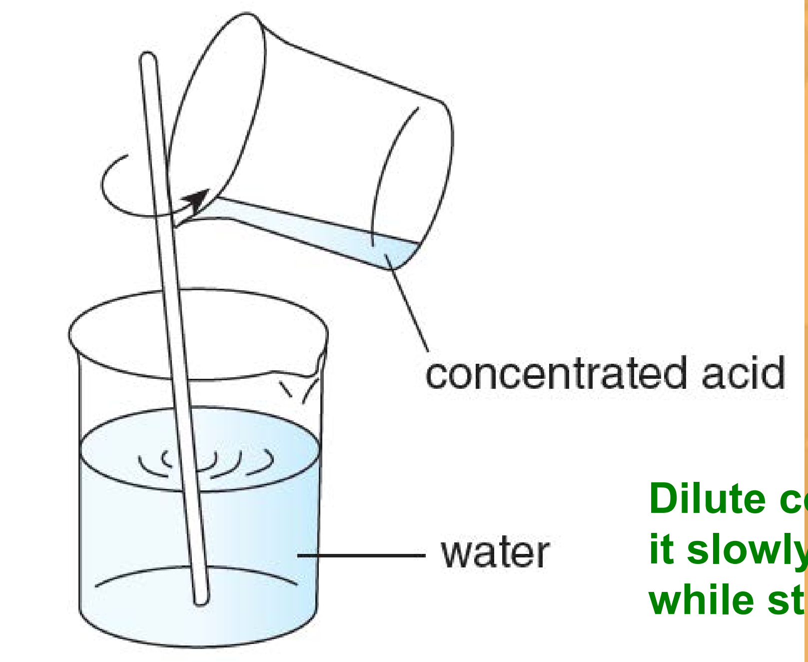
- Ordinary concentrated hydrochloric acid contains about 35% hydrogen chloride by mass. Ordinary concentrated sulphuric acid contains about 98% sulphuric acid by mass.
- Ordinary concentrated nitric acid contains about 70% nitric acid by mass. It tends to decompose to brown nitrogen dioxide gas. Light can speed up the decomposition. Hence the acid is often kept in a brown bottle.
- These concentrated acids have the characteristics of a typical acid. For example, each reacts with a base to give a salt and water.


**Concentrated nitric acid stored in a brown bottle**

# 14.9 Concentrated acids (p.25)

## Diluting concentrated acids

- Concentrated acid is diluted by adding it slowly to a large amount of water while stirring.




**Dilute concentrated acid by adding it slowly to a large amount of water while stirring**

# 14.9 Concentrated acids (p.25)

- Concentrated acid may generate lots of heat when mixed with water. Water is NEVER added to a concentrated acid.
- If you add water to a concentrated acid, the heat released may cause the mixture to violently splash out of the container and sputter onto your face.

# 14.10 Corrosive nature of concentrated acids and alkalis (p.26)

- Concentrated acids and alkalis are corrosive.
- Concentrated acids and alkalis cause chemical burns upon contact with the skin. They can also lead to complications when ingested.


The action of concentrated sulphuric acid on a piece of towel

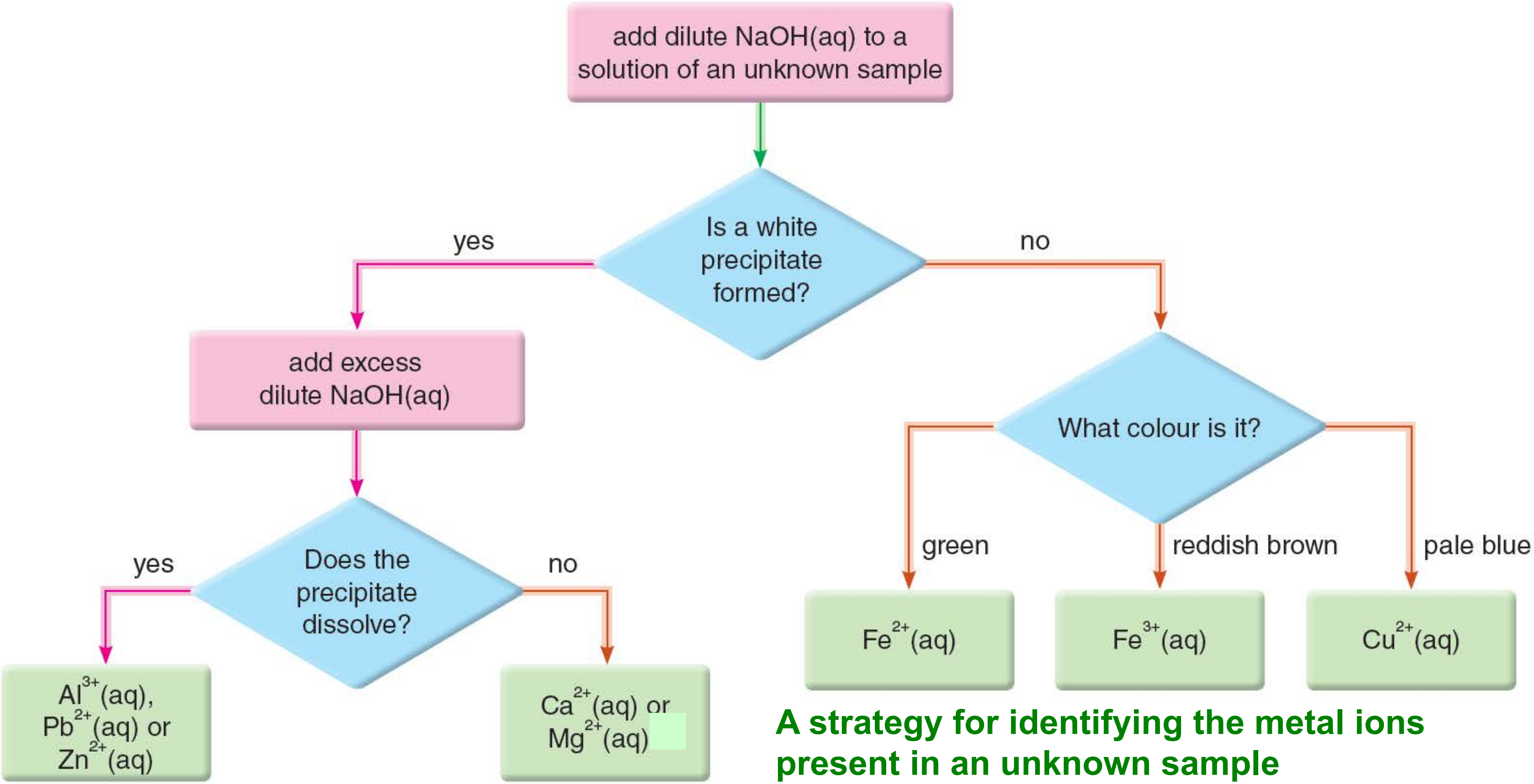
# 14.11 Identifying ions in unknown samples (p.27)

- **Qualitative analysis (定性分析)** deals with the identification of chemical species present in unknown samples.

## Identifying metal ions

- Reacting a solution of an unknown sample with dilute sodium hydroxide solution can help you identify the metal ions present.
- For example, a solution containing copper(II) ions forms a pale blue precipitate when mixed with dilute sodium hydroxide solution.

# 14.11 Identifying ions in unknown samples (p.27)

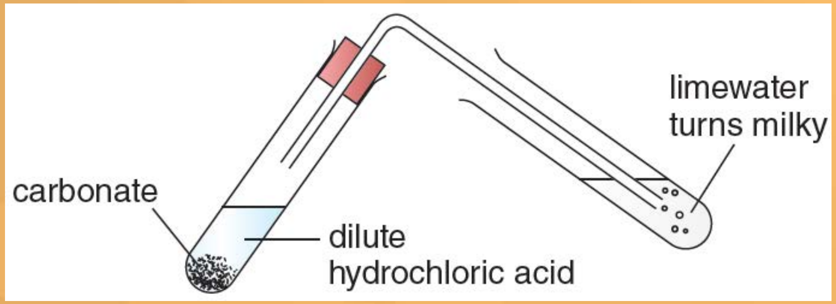



**A strategy for identifying the metal ions present in an unknown sample**

# 14.11 Identifying ions in unknown samples (p.27)

## Identifying carbonate ions

- Carbonate ions ($CO_3^{2-}$) can be identified using a dilute acid such as dilute hydrochloric acid. Dilute hydrochloric acid reacts with a carbonate to produce carbon dioxide gas. The gas turns limewater milky.
- This simple test works either the carbonate is in solid form or in a solution.




A carbonate gives carbon dioxide with dilute hydrochloric acid

A rock containing carbonate gives carbon dioxide gas with dilute hydrochloric acid

# 14.11 Identifying ions in unknown samples (p.27)

**Q** (Example 14.2)

For each of the following pairs of chemicals, suggest a chemical test to distinguish between them. State also the expected observations.

a) $AgNO_3$(aq) and $NaNO_3$(aq)

b) $NH_4Cl$(s) and KCl(s)

# 14.11 Identifying ions in unknown samples (p.27)

**A**

a) Any one of the following:
- Add dilute hydrochloric acid to each solution separately.
  $AgNO_3$(aq) gives a white precipitate.
  $NaNO_3$(aq) gives no observable change.
- Add dilute sodium hydroxide solution to each solution separately.
  $AgNO_3$(aq) gives a brown precipitate.
  $NaNO_3$(aq) gives no observable change.

b) Add dilute sodium hydroxide solution to each solid separately. Warm each mixture.
$NH_4Cl$(s) gives a gas that can turn moist red litmus paper blue (ammonia).
KCl(s) gives no observable change.

# 14.11 Identifying ions in unknown samples (p.27)

**Q** (Example 14.3)

Three unlabeled reagent bottles each contains one of the white solids listed below:

- Anhydrous aluminium sulphate
- Anhydrous zinc sulphate
- Hydrated zinc sulphate

Outline how you would carry out tests to distinguish these three solids.

# 14.11 Identifying ions in unknown samples (p.27)

**A**

Dissolve the solids in water separately.

Add dilute aqueous ammonia to each solution until in excess.

White precipitates form initially for all the solutions. However, only the precipitate formed from aluminium sulphate solution does not dissolve in excess dilute aqueous ammonia. Precipitates formed from the other two zinc sulphate solutions dissolve in excess dilute aqueous ammonia.

Heat solid anhydrous and hydrated zinc sulphate in a test tube respectively. Place a piece of blue cobalt(II) chloride paper in the mouth of the test tube.

Only hydrated zinc sulphate gives water that turns the blue cobalt(II) chloride paper pink upon heating.

# 14.11 Identifying ions in unknown samples (p.27)

## Practice 14.6

For each of the following pairs of substances, suggest a chemical test to distinguish one substance from the other.
State also the expected observations.

a) $Na_2CO_3$(s) and $NaNO_3$(s)

Add dilute hydrochloric acid to each solid separately.
$Na_2CO_3$(s) gives effervescence.
$NaNO_3$(s) gives no observable change.

b) $CaCl_2$(aq) and $ZnCl_2$(aq)

Any one of the following:

- Add dilute sodium hydroxide solution to each solution until in excess.
  $CaCl_2$(aq) gives a white precipitate which does not dissolve in excess dilute sodium hydroxide solution.
  $ZnCl_2$(aq) gives a white precipitate which dissolves in excess dilute sodium hydroxide solution.
- Carry out a flame test.
  $CaCl_2$(aq) gives a brick-red flame.
  $ZnCl_2$(aq) gives no characteristic flame colour.

# 14.12 Drying agents (p.30)

- When a beaker of concentrated sulphuric acid is left in air for some time, the volume of the acid. This is because the acid absorbs water vapour from air.
- Substances which do this are said to be **hygroscopic (吸濕的)**.


**The volume of concentrated sulphuric acid increases when it is left in air**

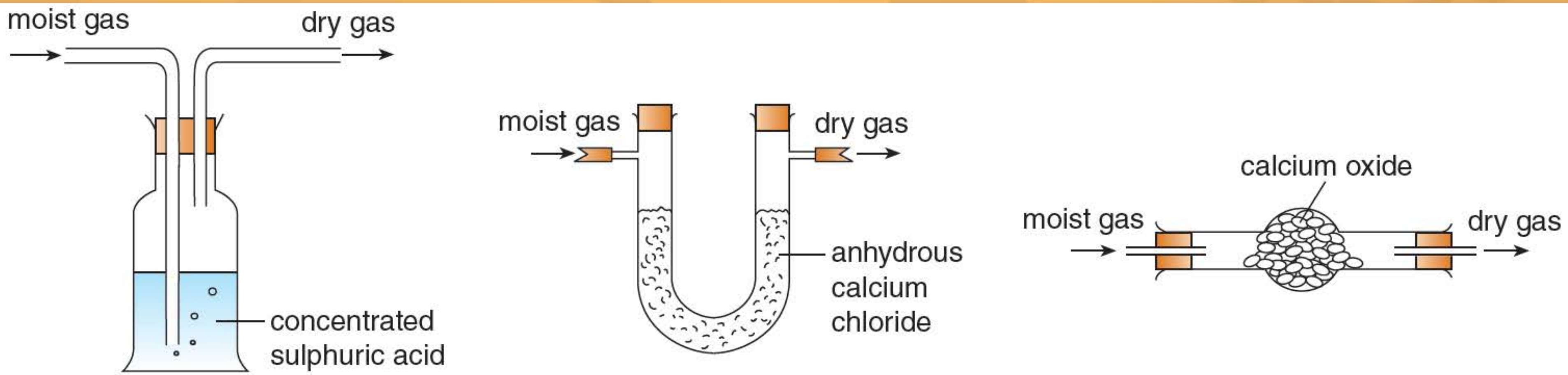
# 14.12 Drying agents (p.30)

- When anhydrous calcium chloride is left in air for some time, it absorbs water vapour from air and eventually forms a very concentrated solution. Substances which behave like this are said to be **deliquescent (潮解的)**.
- Solid sodium hydroxide is also a deliquescent substance.
- Hygroscopic and deliquescent substances are often used as **drying agents (乾燥劑)**.
- Drying agents have found widespread uses in food, electronic products and many manufacturing industries.

Silica gel is used as a drying agent to keep the camera flashlight dry

# 14.12 Drying agents (p.30)

- Three drying agents used in the laboratory are
  - concentrated sulphuric acid;
  - anhydrous calcium chloride;
  - calcium oxide.

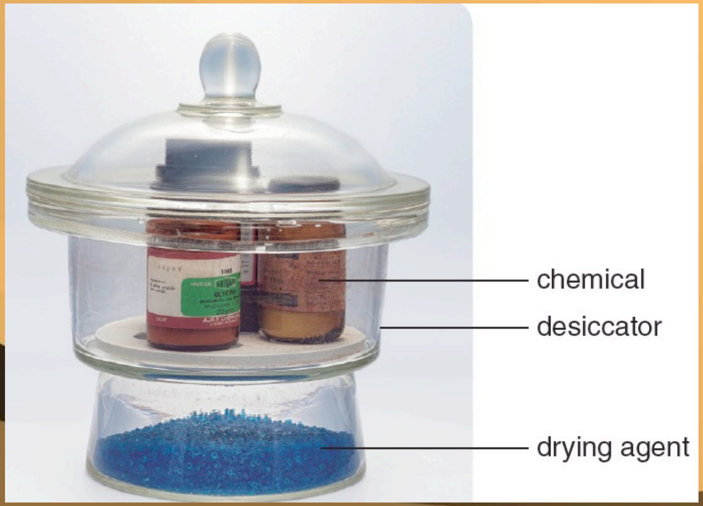



**Concentrated sulphuric acid, anhydrous calcium chloride and calcium oxide can be used to dry gases (from left to right)**

# 14.12 Drying agents (p.30)

- Concentrated sulphuric acid and anhydrous calcium chloride cannot be used to dry ammonia gas because both react with the gas.
- Calcium oxide is used to dry ammonia. However, calcium oxide cannot be used to dry acidic gases such as carbon dioxide and sulphur dioxide.
- Drying agents are used in **desiccators (乾燥器)** to maintain a dry environment for chemicals.

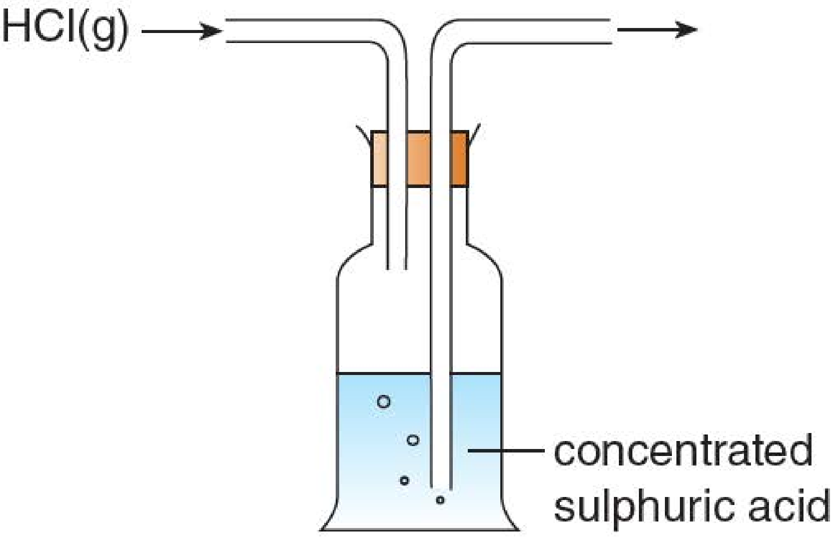



**Using a drying agent in a desiccator for maintaining a dry environment for the chemicals**

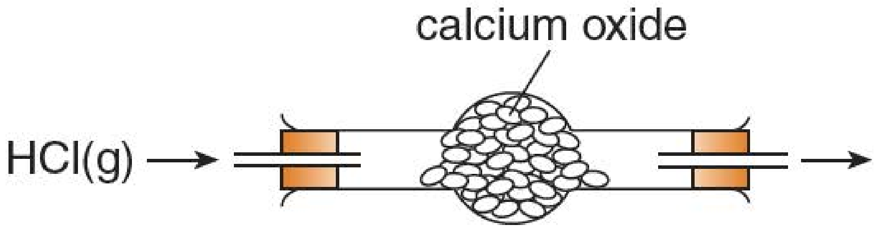
# 14.12 Drying agents (p.30)

## Practice 14.7

In a laboratory class, students were asked to dry a sample of hydrogen chloride gas. Two proposed set-ups were shown below.




*Set-up 1*




*Set-up 2*

# 14.12 Drying agents (p.30)

Practice 14.7 (continued)

a) The teacher commented that both set-ups shown above were inappropriate. Explain why.

Set-up 1

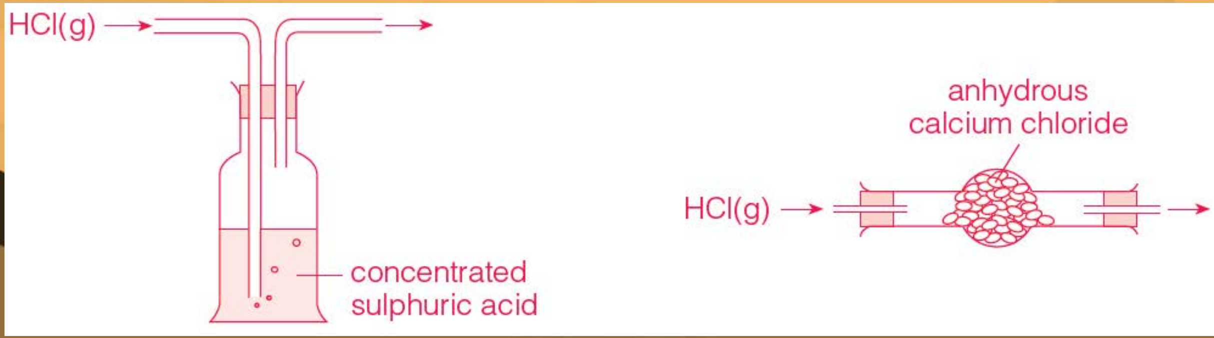
The end of the delivery tube for the incoming gas is above the concentrated sulphuric acid. Thus, the incoming gas does NOT pass through the drying agent.

Set-up 2

Calcium oxide CANNOT be used to dry HCl(g) because calcium oxide reacts with HCl(g).

b) Draw a labelled diagram of a suitable set-up for drying the gas.

Any one of the following:



# Key terms (p.33)

| | | | |
|---|---|---|---|
| ethanoic acid | 乙酸 | sulphuric acid | 硫酸 |
| citric acid | 檸檬酸 | nitric acid | 硝酸 |
| oxalic acid | 草酸 | mineral acid | 礦酸 |
| lactic acid | 乳酸 | base | 鹽基 |
| carbonic acid | 碳酸 | neutralisation | 中和作用 |
| phosphoric acid | 磷酸 | effervescence | 泡騰 |
| hydrochloric acid | 氫氯酸 | dissociation | 離解作用 |

# Key terms (p.33)

| | | | |
|---|---|---|---|
| hydroxonium ion | 水合氫離子 | calcium hydroxide | 氫氧化鈣 |
| basicity | 鹽基度 | aqueous ammonia | 氨水 |
| monobasic acid | 一元酸 | complex salt | 絡鹽 |
| dibasic acid | 二元酸 | qualitative analysis | 定性分析 |
| tribasic acid | 三元酸 | hygroscopic | 吸濕的 |
| alkali | 鹼 | deliquescent | 潮解的 |
| potassium hydroxide | 氫氧化鉀 | drying agent | 乾燥劑 |
| sodium hydroxide | 氫氧化鈉 | | |

# Summary (p.34)

1 Characteristics of dilute acids:

a) Dilute acids have a sour taste.

b) Dilute acids conduct electricity due to the presence of mobile ions.

c) Some reactions of dilute acids are listed in the following table:

| Reaction with | Products formed | Examples |
|---|---|---|
| metals | metal + dilute acid $\longrightarrow$ salt + hydrogen | $Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$<br>$Fe(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2(g)$ |
| bases | oxide or hydroxide of metal + dilute acid $\longrightarrow$ salt + water | $CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$<br>$Zn(OH)_2(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + 2H_2O(l)$ |
| metal carbonates and hydrogencarbonates | metal carbonate or hydrogencarbonate + dilute acid $\longrightarrow$ salt + water + carbon dioxide | $CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$<br>$2NaHCO_3(s \text{ or } aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$ |

# Summary (p.34)

2 An acid is a compound which produces hydrogen ions ($H^+(aq)$) as the only positive ions when dissolved in water.
3 Water must be present for an acid to exhibit its typical properties.
4 The basicity of an acid is the maximum number of hydrogen ions that can be produced by one molecule of the acid.
5 Most oxides and hydroxides of metals are bases. A base is a substance that neutralises an acid to form a salt and water only.
6 Alkalis are bases which are soluble in water.
7 An alkali is a base which releases hydroxide ions ($OH^-(aq)$) when dissolved in water.

# Summary (p.34)

8 Characteristics of dilute solutions of alkalis:

a) Dilute solutions of alkalis feel slippery to the skin and have a bitter taste.

b) Dilute solutions of alkalis conduct electricity due to the presence of mobile ions.

c) Adding dilute sodium hydroxide solution to solutions containing certain metal ions until in excess gives metal hydroxide precipitates as listed in the following table:

# Summary (p.34)

| Adding NaOH(aq) to solution containing | Colour of precipitate formed | Precipitate dissolves in excess NaOH(aq)? | Ionic equation(s) |
|---|---|---|---|
| $Ca^{2+}(aq)$ | white | ✘ | $Ca^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Ca(OH)_2(s)$ |
| $Mg^{2+}(aq)$ | white | ✘ | $Mg^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Mg(OH)_2(s)$ |
| $Al^{3+}(aq)$ | white | ✔ (a colourless solution forms) | $Al^{3+}(aq) + 3OH^{-}(aq) \longrightarrow Al(OH)_3(s)$<br>$Al(OH)_3(s) + OH^{-}(aq) \longrightarrow [Al(OH)_4]^{-}(aq)$ |
| $Pb^{2+}(aq)$ | white | ✔ (a colourless solution forms) | $Pb^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Pb(OH)_2(s)$<br>$Pb(OH)_2(s) + 2OH^{-}(aq) \longrightarrow [Pb(OH)_4]^{2-}(aq)$ |
| $Zn^{2+}(aq)$ | white | ✔ (a colourless solution forms) | $Zn^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Zn(OH)_2(s)$<br>$Zn(OH)_2(s) + 2OH^{-}(aq) \longrightarrow [Zn(OH)_4]^{2-}(aq)$ |
| $Fe^{2+}(aq)$ | green | ✘ | $Fe^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Fe(OH)_2(s)$ |
| $Fe^{3+}(aq)$ | reddish brown | ✘ | $Fe^{3+}(aq) + 3OH^{-}(aq) \longrightarrow Fe(OH)_3(s)$ |
| $Cu^{2+}(aq)$ | pale blue | ✘ | $Cu^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Cu(OH)_2(s)$ |

# Summary (p.34)

8 d) Adding dilute aqueous ammonia to solutions containing certain metal ions until in excess gives metal hydroxide precipitates as listed in the following table:

| Adding $NH_3(aq)$ to solution containing | Colour of precipitate formed | Precipitate dissolves in excess $NH_3(aq)$? | Ionic equation(s) |
|---|---|---|---|
| $Mg^{2+}(aq)$ | white | ✘ | $Mg^{2+}(aq) + 2OH^-(aq) \longrightarrow Mg(OH)_2(s)$ |
| $Al^{3+}(aq)$ | white | ✘ | $Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$ |
| $Pb^{2+}(aq)$ | white | ✘ | $Pb^{2+}(aq) + 2OH^-(aq) \longrightarrow Pb(OH)_2(s)$ |
| $Zn^{2+}(aq)$ | white | ✔ (a colourless solution forms) | $Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$<br>$Zn(OH)_2(s) + 4NH_3(aq) \longrightarrow [Zn(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$ |
| $Fe^{2+}(aq)$ | green | ✘ | $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$ |
| $Fe^{3+}(aq)$ | reddish brown | ✘ | $Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$ |
| $Cu^{2+}(aq)$ | pale blue | ✔ (a deep blue solution forms) | $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$<br>$Cu(OH)_2(s) + 4NH_3(aq) \longrightarrow [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$ |

# Summary (p.34)

8 e) Heating solids or solutions of ammonium compounds with solutions of alkalis liberates ammonia gas.

e.g. $NH_4NO_3$(s or aq) + NaOH(aq) $\xrightarrow{\text{heat}}$ $NH_3$(g) + $NaNO_3$(aq) + $H_2O$(l)

or

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

9 Concentrated acids and alkalis are corrosive.

10 Concentrated sulphuric acid, anhydrous calcium chloride and calcium oxide are common drying agents.

# Unit Exercise (p.37)

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

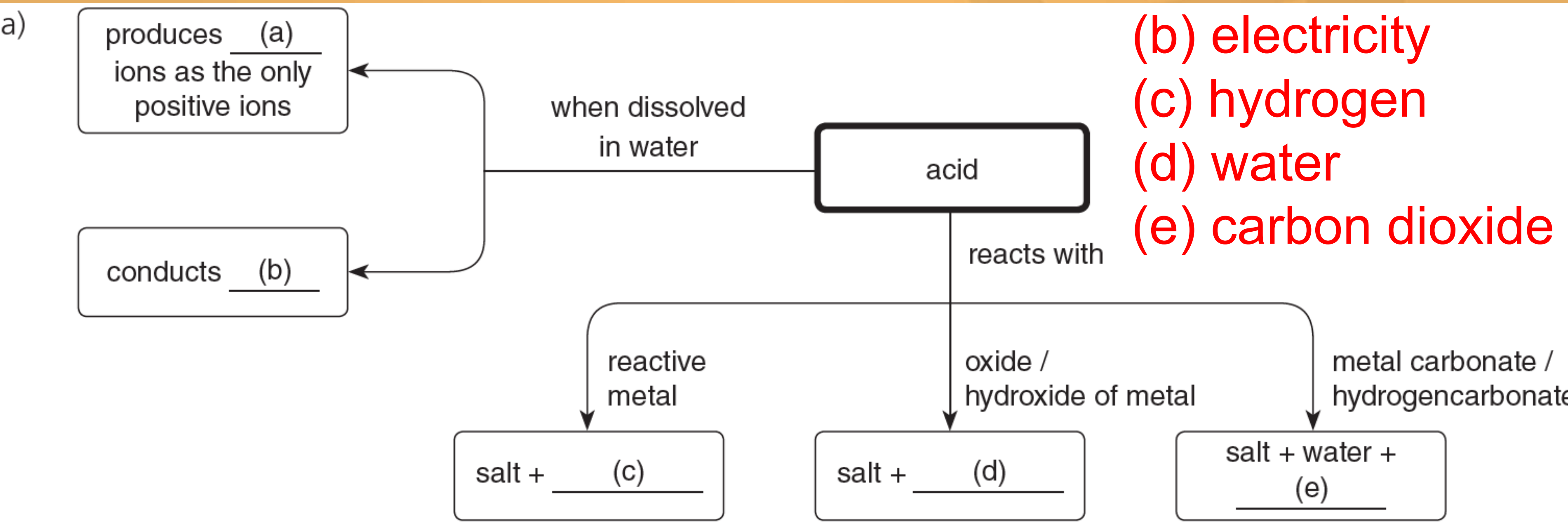
 **question targeted at level 3 and above;**
 **question targeted at level 4 and above;**
 **question targeted at level 5.**
**‘ * ’ indicates 1 mark is given for effective communication.**

# Unit Exercise (p.37)

## PART I KNOWLEDGE AND UNDERSTANDING

1 Complete the following concept map.

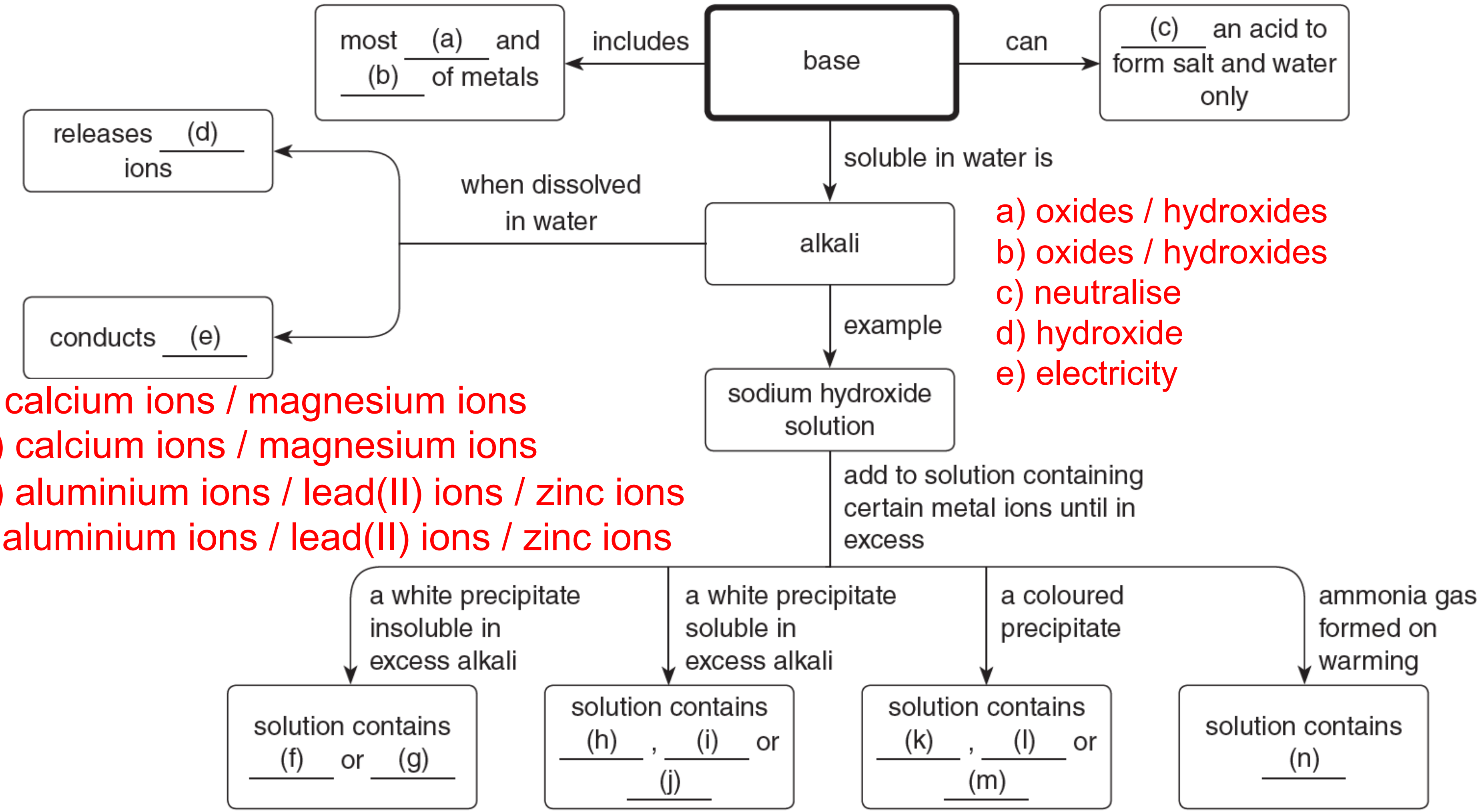
(a) hydrogen
(b) electricity
(c) hydrogen
(d) water
(e) carbon dioxide



# Unit Exercise (p.37)

l) copper(II) ions / iron(II) ions / iron(III) ions
m) copper(II) ions / iron(II) ions / iron(III) ions
n) ammonium ions

b)




a) oxides / hydroxides
b) oxides / hydroxides
c) neutralise
d) hydroxide
e) electricity

f) calcium ions / magnesium ions
g) calcium ions / magnesium ions
h) aluminium ions / lead(II) ions / zinc ions
i) aluminium ions / lead(II) ions / zinc ions

j) aluminium ions / lead(II) ions / zinc ions
k) copper(II) ions / iron(II) ions / iron(III) ions

# Unit Exercise (p.37)

## PART II MULTIPLE CHOICE QUESTIONS

2 Which of the following statements concerning acids is correct?

A Nitric acid is used as a fertiliser.
B Hydrochloric acid is produced in human stomach.
C Ethanoic acid is a non-electrolyte.
D The following hazard warning label should be displayed on a bottle of concentrated hydrochloric acid.

Answer: B

# Unit Exercise (p.37)

3 Magnesium oxide reacts with hydrochloric acid according to the chemical equation below.

$$MgO(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$$

What is the ionic equation for this reaction?

A $Mg^{2+}(s) + 2Cl^-(aq) \longrightarrow MgCl_2(aq)$
B $MgO(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2O(l)$
C $MgO(s) + 2H^+(aq) + 2Cl^-(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$
D $MgO(s) + 2Cl^-(aq) \longrightarrow MgCl_2(aq) + O^{2-}(l)$

Answer: B

# Unit Exercise (p.37)

4 Which of the following is NOT a typical property of a dilute acid?

A It reacts with all metals to produce hydrogen.
B It reacts with carbonates to produce carbon dioxide.
C It can conduct electricity.
D It is neutralised by bases.

Answer: A

Explanation:
Unreactive metals (e.g. copper) have NO reaction with dilute acid.

# Unit Exercise (p.37)

5 Dilute sodium hydroxide solution is added to a 0.1 M solution until in excess. Which of the following combinations is correct?

| | Solution | Observation |
|---|---|---|
| A | zinc sulphate | white precipitate formed |
| B | calcium nitrate | white precipitate formed |
| C | lead(II) nitrate | yellow precipitate formed |
| D | iron(III) sulphate | dirty green precipitate formed |

Answer: B

*(HKDSE, Paper 1A, 2018, 6)*

# Unit Exercise (p.37)

6 Which of the following statements about dilute sulphuric acid is INCORRECT?

A It is a mineral acid.
B It contains hydrogen ions.
C It is a dibasic acid.
D It has a slippery feel.

Answer: D

# Unit Exercise (p.37)

7 Compound X is soluble in water. Addition of dilute sodium hydroxide solution to a solution of X gives a precipitate. The precipitate dissolves upon the addition of excess sodium hydroxide solution. X may be

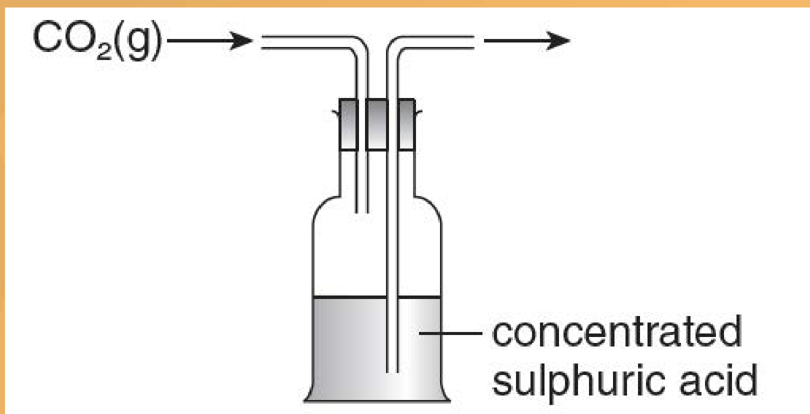
A ammonium sulphate.
B calcium chloride.
C lead(II) nitrate.
D iron(II) sulphate.

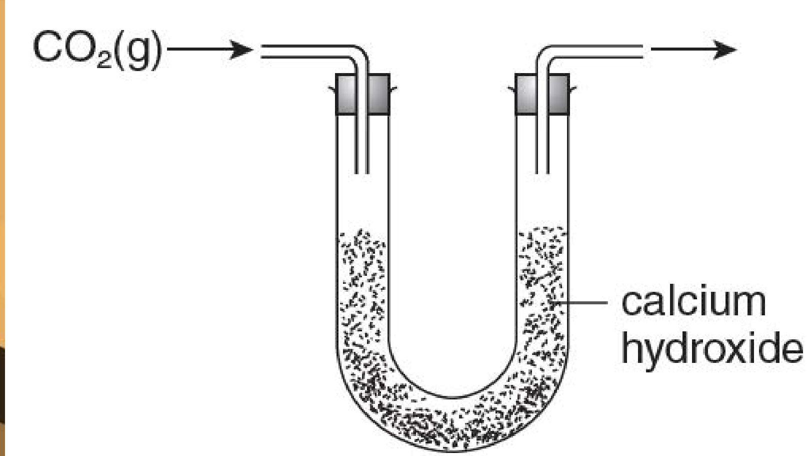
Answer: C

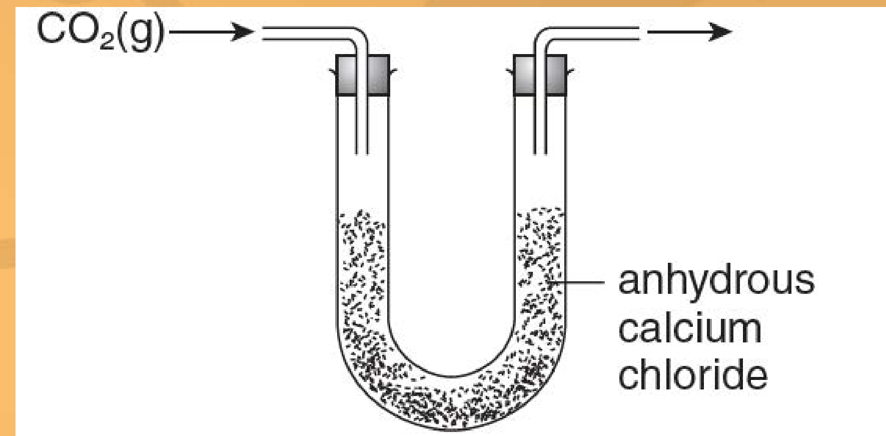
Explanation:
Option A — The end of the delivery tube for the incoming gas is above the concentrated sulphuric acid. Thus, the incoming gas does not pass through the drying agent.
Options B and D — Calcium hydroxide and calcium oxide are basic substances. They react with carbon dioxide gas.

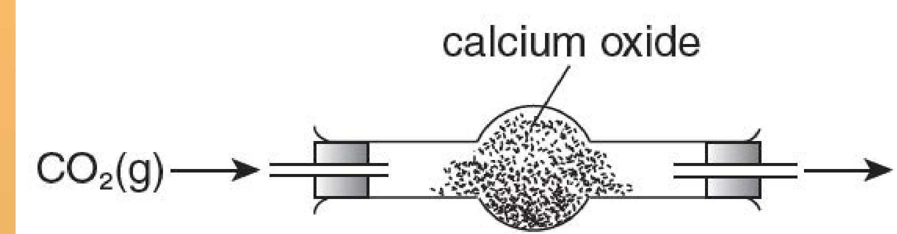
# Unit Exercise (p.37)

8 Which of the following set-ups can be used to dry carbon dioxide gas?

A



B



C



D



Answer: C

# Unit Exercise (p.37)

9 Solid Y is soluble in cold water. When an aqueous solution of Y is added separately to sodium hydroxide solution and to acidified silver nitrate solution, a white precipitate is formed in both cases. Which of the following compounds might Y be?

A Ammonium carbonate
B Zinc carbonate
C Lead(II) chloride
D Magnesium chloride

Answer: D

*(HKDSE, Paper 1A, 2013, 3)*

# Unit Exercise (p.37)

10 Which of the following statements about limestone is / are correct?

(1) It gives a golden yellow flame in a flame test.
(2) It gives a colourless gas when heated strongly.
(3) It dissolves in dilute sulphuric acid to give a clear solution.

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

*(HKDSE, Paper 1A, 2013, 19)*

Answer: B

# Unit Exercise (p.37)

11 Which of the following statements concerning NaOH(aq) and $NH_3$(aq) is / are correct?

(1) Both of them can react with $MgCl_2$(aq).

(2) Both of them can form a deep blue solution with $Cu(OH)_2$(s).

(3) NaOH(aq) can react with $CH_3COOH$(aq), but $NH_3$(aq) cannot.

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

Answer: A

*(HKDSE, Paper 1A, 2017, 17)*

# Unit Exercise (p.37)

12 Which of the following hazard warning labels should be displayed on a reagent bottle storing concentrated sulphuric acid?

(1) 

(2) 

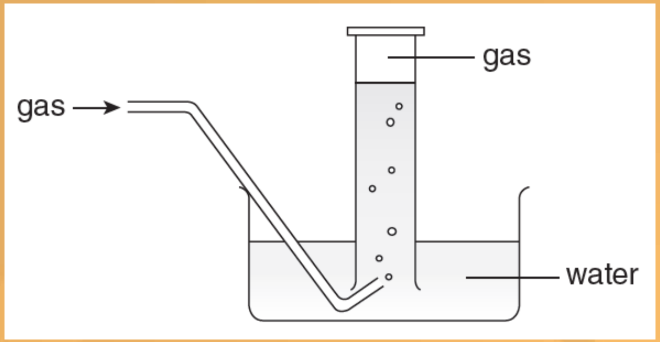
(3) 

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

Answer: D

# Unit Exercise (p.37)

13




Which of the following gases can be collected by the set-up shown above?

(1) Carbon dioxide
(2) Hydrogen chloride
(3) Hydrogen

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

Explanation:
(2) Hydrogen chloride is extremely soluble in water. It is denser than air and can be collected by downward delivery or by using a gas syringe.

Answer: C

# Unit Exercise (p.37)

## PART III STRUCTURED QUESTIONS

14 For each of the following experiments involving acids, state the expected observation, and write a chemical equation for the reaction involved.

a) Zinc is added to dilute hydrochloric acid.

Gas bubbles are given off. / Zinc dissolves in the acid. (1)

$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$ (1)

b) Solid copper(II) oxide is added to dilute sulphuric acid.

Solid copper(II) oxide dissolves in the acid. / A blue solution is formed. (1)

$CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$ (1)

# Unit Exercise (p.37)

14 (continued)

c) Solid magnesium carbonate is added to dilute hydrochloric acid.

Effervescence occurs. / Solid magnesium carbonate dissolves in the acid. (1)

$MgCO_3(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$ (1)

d) Dilute sulphuric acid is added to potassium carbonate solution.

Effervescence occurs. (1)

$K_2CO_3(aq) + H_2SO_4(aq) \longrightarrow K_2SO_4(aq) + H_2O(l) + CO_2(g)$ (1)

# Unit Exercise (p.37)

15 For each of the following experiments, state the expected observation(s), and write the ionic equation(s) for the reaction(s) involved.

a) Water is added to a solid mixture of citric acid and sodium hydrogencarbonate.

b) Dilute sodium hydroxide solution is added to aluminium nitrate solution until in excess.

c) Dilute sodium hydroxide solution is mixed with ammonium chloride solution and warm.

d) Dilute aqueous ammonia is added to copper(II) sulphate solution until in excess.

e) Dilute aqueous ammonia is added to zinc sulphate solution until in excess.

# Unit Exercise (p.37)

15 a) Effervescence occurs. (1)

$NaHCO_3(s) + H^+(aq) \longrightarrow Na^+(aq) + H_2O(l) + CO_2(g)$ (1)

or $HCO_3^-(aq) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g)$

b) A white precipitate forms. (1)

The precipitate dissolves in excess dilute sodium hydroxide solution to give a colourless solution. (1)

$Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$ (1)

$Al(OH)_3(s) + OH^-(aq) \longrightarrow [Al(OH_4)]^-(aq)$ (1)

c) Ammonia gas is given off. (1)

$NH_4+(aq) + OH^-(aq) \longrightarrow NH_3(g) + H_2O(l)$ (1)

d) A blue precipitate forms. (1)

The precipitate dissolves in excess dilute aqueous ammonia to give a deep blue solution. (1)

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

$Cu(OH)_2(s) + 4NH_3(aq) \longrightarrow [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$ (1)

e) A white precipitate forms. (1)

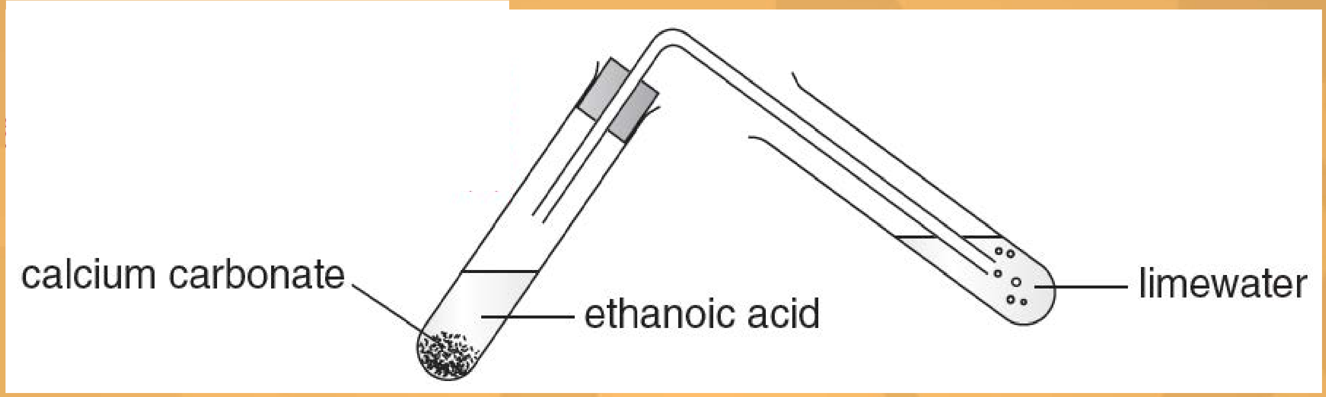
The precipitate dissolves in excess dilute aqueous ammonia to give a colourless solution. (1)

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

$Zn(OH)_2(s) + 4NH_3(aq) \longrightarrow [Zn(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$ (1)

# Unit Exercise (p.37)

16 The set-up shown below is used to investigate the reaction of ethanoic acid with calcium carbonate.




a) Describe TWO changes that will be observed.

Any two of the following:

- Effervescence occurs. (1)
- Calcium carbonate decreases in size / dissolves. (1)
- Limewater turns milky. (1)

b) Write the chemical equation for the reaction involved.

$CaCO_3(s) + 2CH_3COOH(aq) \longrightarrow (CH_3COO)_2Ca(aq) + H_2O(l) + CO_2(g)$ (1)

c) Name the salt formed. Calcium ethanoate (1)

# Unit Exercise (p.37)

17 For the following experiment, state the expected observation, and write the chemical equation(s) for the reaction(s) involved.

Passing carbon dioxide gas into limewater until in excess.

*(HKDSE, Paper 1B, 2015, 2(a))*

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

# Unit Exercise (p.37)

18 Consider the experiment below and answer the questions that follow.

Dilute sodium hydroxide solution is added to copper(II) sulphate solution.

a) State the expected observation.

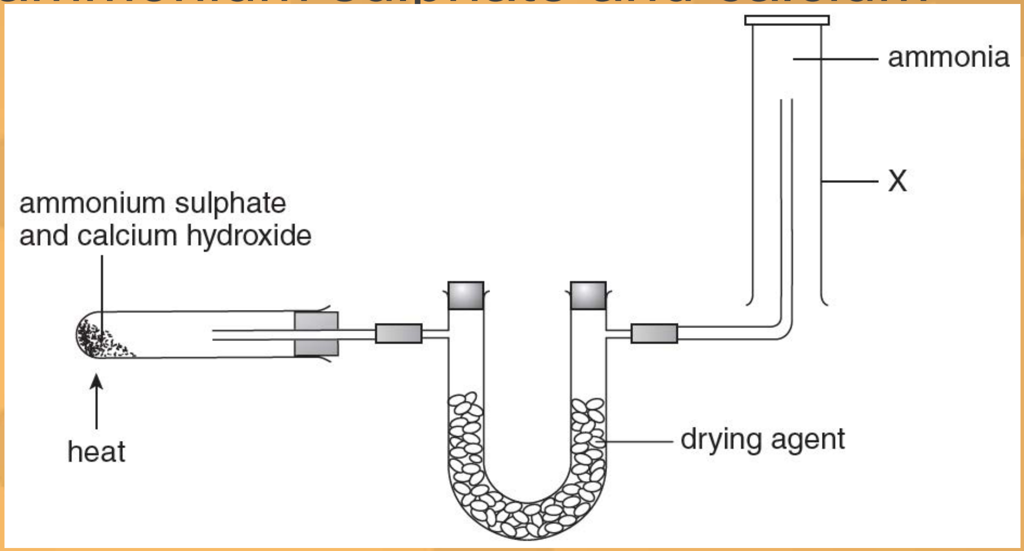
b) Write the chemical equation for the reaction that occurs.

*(HKDSE, Paper 1B, 2014, 9(a))*

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

# Unit Exercise (p.37)

19 Ammonia gas can be prepared using the set-up below. A mixture of two solids, ammonium sulphate and calcium hydroxide, is heated.




a) Write the chemical equation for the reaction between ammonium sulphate and calcium hydroxide.

$(NH_4)_2SO_4(s) + Ca(OH)_2(s) \longrightarrow 2NH_3(g) + CaSO_4(s) + 2H_2O(l)$ (1)

b) Suggest a suitable drying agent for drying ammonia.

Calcium oxide (1)

# Unit Exercise (p.37)

19 (continued)

c) Name the apparatus labelled X.

Gas jar (1)

d) Why is the ammonia collected by upward delivery as shown, but NOT over water?

Ammonia is less dense than air. Thus, it can be collected by upward delivery. (1)

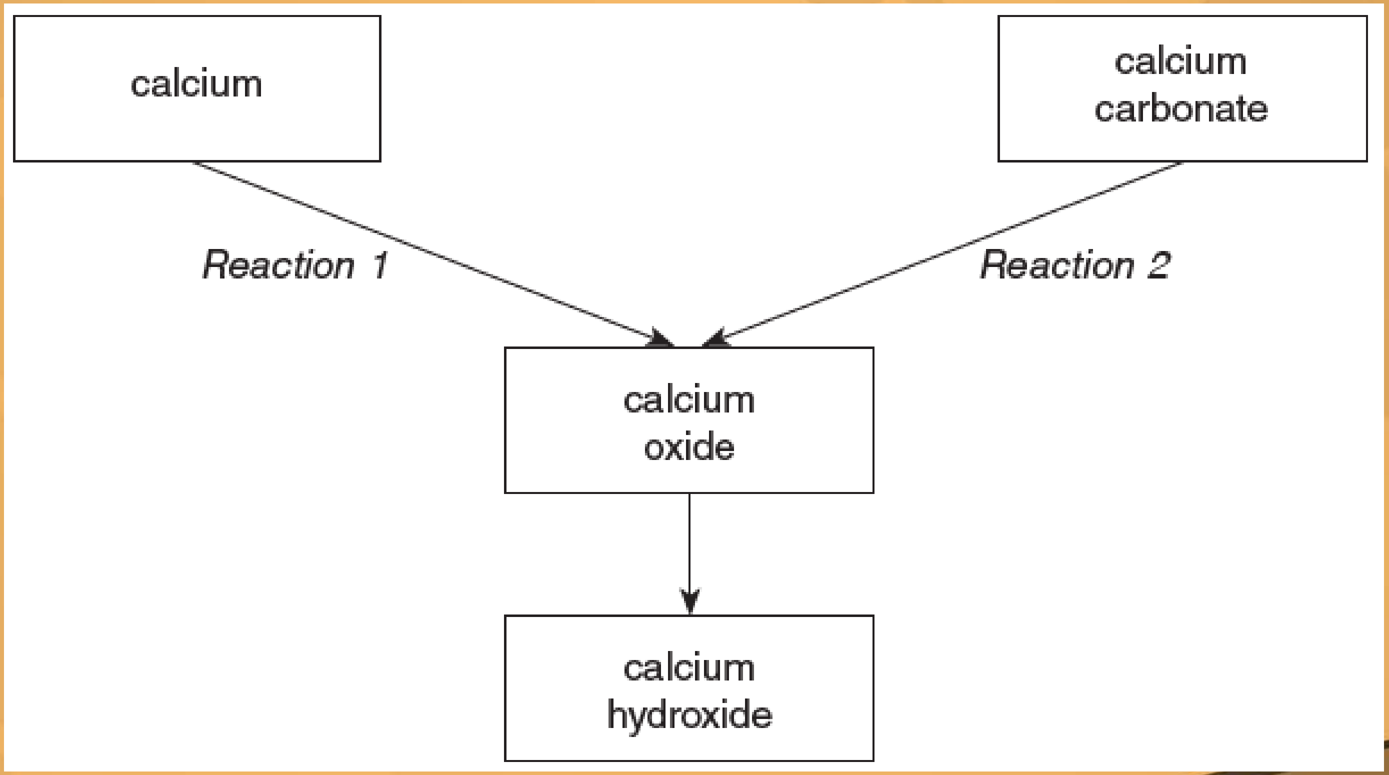
Ammonia is very soluble in water. Thus, it is NOT collected over water. (1)

e) Give a test for ammonia gas.

Ammonia turns moist red litmus paper blue. (1)

# Unit Exercise (p.37)

20 The diagram below shows some reactions of calcium and its compounds.



# Unit Exercise (p.37)

20 (continued)

a) *Reactions 1* and *2* both form calcium oxide. Write a chemical equation for each of the reactions.

$2Ca(s) + O_2(g) \longrightarrow 2CaO(s)$ (1)

$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$ (1)

b) Calcium hydroxide is both a base and an alkali. Explain what are meant by the terms 'base' and 'alkali'.

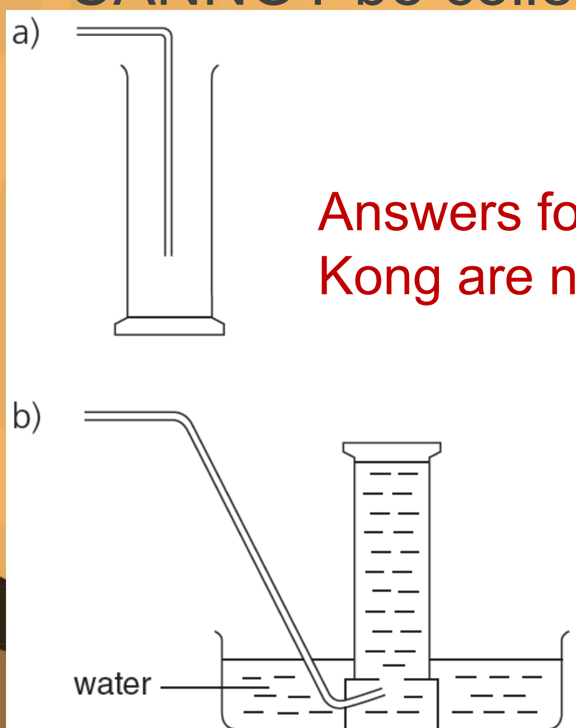
A base is a substance that neutralises an acid to form a salt and water only. (1)

An alkali is a base which is soluble in water. (1)

# Unit Exercise (p.37)

21 Barium (Ba) is an element in Group II of the Periodic Table. Its chemical properties are similar to those of calcium.

A gas with a pungent smell is formed when $Ba(OH)_2(s)$ is heated with $NH_4Cl(s)$. State the reason why the gas CANNOT be collected by each of the following methods.




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

*(HKDSE, Paper 1B, 2017, 1(b))*

# Unit Exercise (p.37)

22 Solid W was analysed by a student. W was a carbonate. The tests on W and some of the observations were shown in the following table.

| Test on solid W | | Observation(s) |
|---|---|---|
| 1 | Dilute hydrochloric acid was added to solid W.<br>The gas given off was tested. | ? |
| 2 | Dilute sodium hydroxide solution was added to solid W and the mixture was heated.<br>The gas given off was tested with moist red litmus paper. | The gas turned moist red litmus paper blue. |

a) i) Complete the observations in *Test 1*. Effervescence occurred. (1) The gas turned limewater milky.(1)

ii) What was the gas given off in *Test 2*?
Ammonia (1)

b) What conclusion can be drawn about solid W?
Solid W is ammonium carbonate. (1)

# Unit Exercise (p.37)

23 For each of the following pairs of substances, suggest a test to distinguish one substance from the other and state the expected observations.

a) Calcium chloride solution and zinc chloride solution

Any one of the following:

- Add dilute sodium hydroxide solution to each solution until in excess. (1)
  $CaCl_2$(aq) gives a white precipitate which does not dissolve in excess dilute sodium hydroxide solution.
  $ZnCl_2$(aq) gives a white precipitate which dissolves in excess dilute sodium hydroxide solution. (1)
- Carry out a flame test. (1)
  $CaCl_2$(aq) gives a brick-red flame.
  $ZnCl_2$(aq) gives no characteristic flame colour. (1)

# Unit Exercise (p.37)

23 (Continued)

b) Solid sodium chloride and solid sodium carbonate

c) Iron(II) sulphate solution and iron(III) sulphate solution

b) Any one of the following:

- Add dilute hydrochloric acid to each solid separately. (1)
  Solid sodium carbonate gives effervescence.
  Solid sodium chloride gives no observable change. (1)
- Dissolve each solid in water. Add dilute nitric acid followed by silver nitrate solution to each soluiton. (1)
  Solution of sodium carbonate gives effervescence with dilute nitric acid but no precipitate with silver nitrate solution.
  Solution of sodium chloride gives a white precipitate. (1)

c) Add dilute sodium hydroxide solution / dilute aqueous ammonia to each solution. (1)
Iron(II) sulphate solution gives a green precipitate.
Iron(III) sulphate solution gives a reddish brown precipitate. (1)

# Unit Exercise (p.37)

24 Two tests were performed on the solution of compound X to identify the ions in the compound.
The results were recorded in the table below.

| Test | | Observation |
|---|---|---|
| 1 | adding dilute sodium hydroxide solution | a reddish brown precipitate formed |
| 2 | adding dilute nitric acid, followed by silver nitrate solution | a white precipitate formed |

a) Identify the TWO ions in compound X.

Iron(III) ion (1) Chloride ion (1)

b) Write an ionic equation for the reaction that occurred in each test.

$Fe^{3+}(aq) + 3OH^{-}(aq) \longrightarrow Fe(OH)_3(s)$ (1)

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

# Unit Exercise (p.37)

25 A student finds an unlabelled bottle containing a white powder. He suspects that the powder may be either sodium carbonate, sodium chloride or sodium hydroxide. Describe how the student could identify the substance. Your answer must include the expected observations for EACH substance.

Add dilute hydrochloric acid to each solid separately. (1)
The powder is sodium carbonate if effervescence occurs. (1)
The powder is sodium hydroxide if there is a temperature rise. (1)
The powder is sodium chloride if there is no change. (1)

*(WJEC GCSE Science A (Higher Tier), Chem. 1, Jan. 2012, 9(a))*