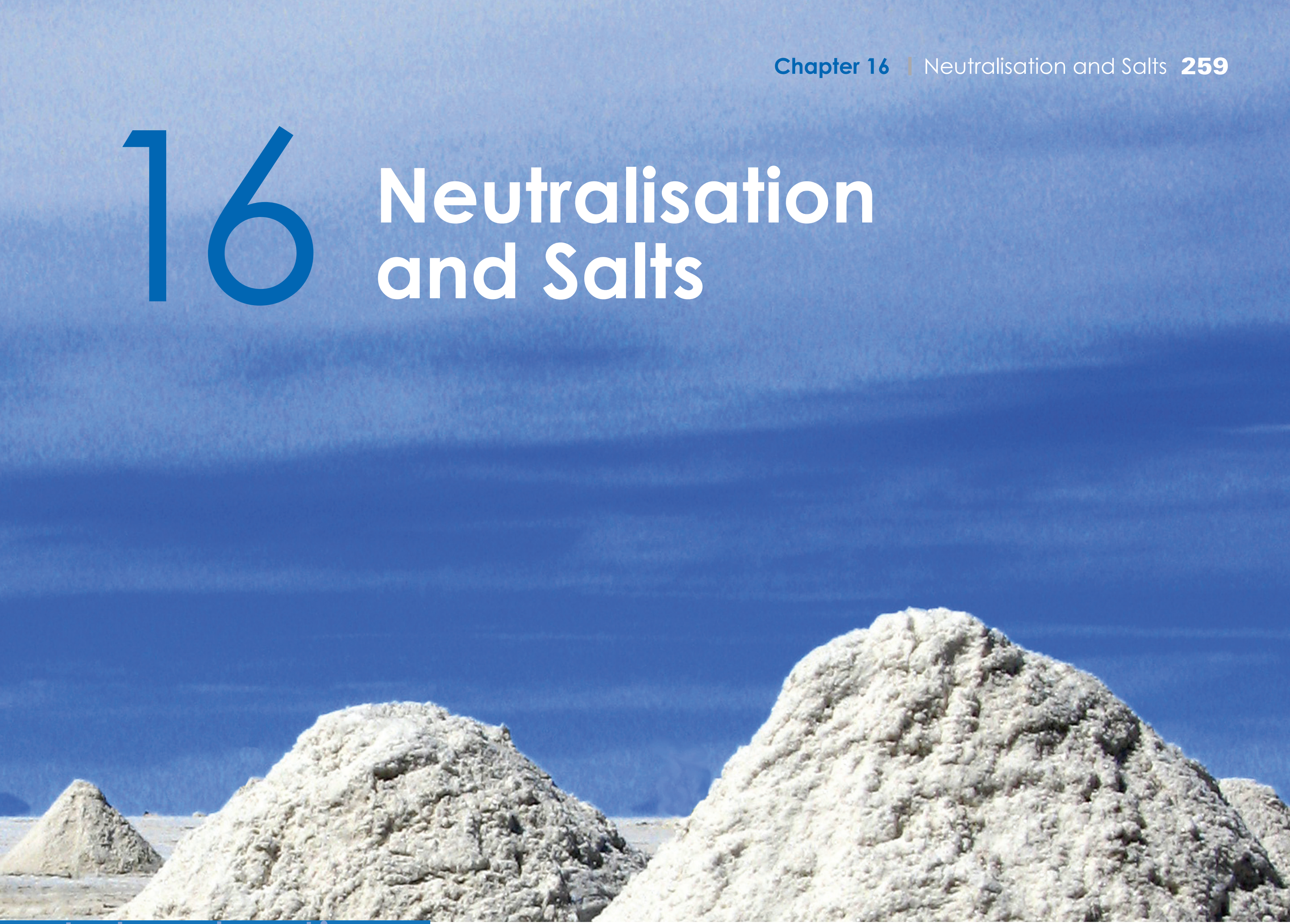
16 Neutralisation and Salts



Introduction

From the basic ideas of acids, bases, ions and pH introduced in Chapter 15, the chemistry of the neutralisation of acids and bases and the formation of salts is studied in this chapter together with applications of neutralisation in daily life. Students also learn how to select an appropriate method for the preparation of a salt and to carry out the preparation in the laboratory.

Chapter Opener (page ?)

1. To open the chapter, the following questions could be discussed. Precise answers are not needed at this stage.

   Whatl is neutralisation?

   Answer: A chemical reaction in which an acid and a base react.

   With a bee sting, what kind of substance causes the pain? Why can we use baking soda to relieve the pain from the sting?

   Answer: The substance that causes the pain from a bee sting is an acid. Baking soda contains an alkali, sodium hydrogencarbonate, which can neutralise the acid from a bee sting.

   What is the formula of sodium chloride? What acid and alkali can react to form it?

   Answer: $NaCl$. It is formed when hydrochloric acid and sodium hydroxide react.

2. Carry out an 'Inquiry Preview.'

Learning Outcomes

After completing this chapter, students should be able to:

- describe neutralisation as the reaction between hydrogen ions and hydroxide ions to produce water
- classify oxides as acidic, basic, amphoteric or neutral based on metallic/non-metallic character
- describe applications of neutralisation in daily life including the importance of controlling pH in soils and how excess acidity in soils can be treated using calcium hydroxide
- describe the general rules of solubility of common salts
- describe the techniques used in the preparation, separation and purification of salts
- suggest a method of preparing a given salt using suitable materials, given appropriate information

Teaching pointers

16.1 What is Neutralisation? (page 244)

Stimulation

During a neutralisation reaction, the properties of the acid and the base (or alkali) are taken away or destroyed. Introduce this topic with a simple experiment related to indigestion and the use of antacids. Place a little vinegar (rather than hydrochloric acid, which is present in our stomach) in a glass. Get students to taste the vinegar to confirm its sour taste. Then add an antacid tablet (preferably a carbonate or a hydrogencarbonate so that students can see the gas produced). After the reaction is completed, get students to taste the solution again to confirm that the sour taste, and therefore the acid, is no longer present. (Before carrying out the demonstration, check that the volume of acid used is able to be neutralised by the antacid tablet.)

While carrying out the demonstration, ask the class the following questions:

- What is the meaning of the word 'antacid'? [An antacid is a substance that reacts against / neutralises an acid.]
- Look at the label on a bottle or packet of antacid. What substances does it contain? [For example, it contains metal hydroxides or carbonates.]
- What do we call a solution that is neither acidic nor alkaline? [Neutral solution]
- Do you think toothpaste contains an acid or an alkali? Explain. [Acids cause tooth decay. Therefore toothpaste contains an alkali to neutralise the acid. See also page 244 of the Textbook.]
- Alkalis are also bases. Name some bases that are
  (a) alkalis [Any soluble hydroxide or ammonia.]
  (b) not alkalis [Any insoluble metal oxide or hydroxide.]

Teaching pointers

16.2 What Occurs During Neutralisation? (page 244)

1. Demonstrate the neutralisation of dilute hydrochloric acid and sodium hydroxide solution and the isolation of sodium chloride as shown in Figure 16.2 on page 245 of the Textbook. Point out the use of an indicator to show that neutralisation has occurred. This demonstration introduces the following important points:

- The concept of neutralisation
- The concept of a titration
- The concept of end point
- The formation of a salt
- A method to isolate a salt

Note: This demonstration is not able to show that heat is produced in a neutralisation reaction, although a thermometer could be used.

2. From the reaction between hydrochloric acid and sodium hydroxide solution, get the class to work out the ionic equation for neutralisation reactions and discuss its generality to all acid-alkali reactions.

3. Extend the concept of neutralisation from alkalis to bases and lead the class to the definition of neutralisation.

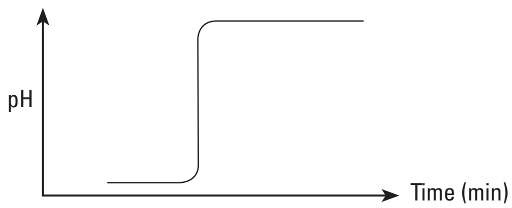
4. With our definition of neutralisation, discuss with the class that the reaction between a carbonate and an acid is not a neutralisation reaction as carbon dioxide, in addition to salt and water, is also formed.
(See also question 3 of Skills Practice on page 246 of the Textbook.)

Experiment 16.1: (PWB page 81–82)

In this experiment, the change in pH during neutralisation is measured using a pH sensor connected to a computer. You may conduct this experiment either as a teacher demonstration or as a class activity.

Here are some comments on this experiment:

- One of the difficulties with data-logging experiments is the need to calibrate the sensor. You will need to help students with this step. Follow the instructions that come with the software program.
- You may need to modify the experiment to suit the kind of apparatus available.
- The experiment only gives an approximate answer and is less accurate than a conventional titration. However, students should be told that it is possible to achieve very accurate results using appropriate apparatus and software.
- A typical graph is shown below:



- The time taken for the reaction to be completed is about 70 seconds.
- In the experiment, the burette contains sodium hydroxide solution. Normally, sodium hydroxide is not placed in a burette with a glass stopcock. This is because any alkali not washed out of the burette after the titration may react with air to form sodium carbonate and cause the stopcock to stick. However, carrying out the titration as shown makes the colour change at the end point easier to be observed. Therefore, get students to wash the burettes thoroughly after use or use burettes without glass stopcocks.

Skills Practice (page 246)

1. The salt is potassium sulfate, K_2SO_4.
2. (a) $2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$
   The salt formed is sodium sulfate.
   (b) $KOH(aq) + HNO_3(aq) \longrightarrow KNO_3(aq) + H_2O(l)$
   The salt formed is potassium nitrate.
   (c) $MgO(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$
   The salt formed is magnesium chloride.
3. (a) $CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$
   (b) Based on the definition of neutralisation as the reaction between an acid and a base to form a salt and water *only*, the reaction of a carbonate with an acid is not a neutralisation reaction as carbon dioxide is also formed.

Teaching pointers

16.3 How are Oxides Classified? (page 246)

1. Emphasise that
   (a) acidic oxides react with alkalis to produce salts,
   (b) basic oxides react with acids to produce salts,
   (c) amphoteric oxides react with both acids and alkalis to produce salts, and
   (d) neutral oxides do not react with acids or bases and do not form salts.
2. The acidic oxide sulfur dioxide is indicated on the lists of ingredients of some foods and drinks. Show examples of these products to the class. See the notes on the next page on its health risks.

Skills Practice (page 247)

1. The formula of water contains H (hydrogen) and O (oxygen). If H_2O did not have the common name *water*, it would be called hydrogen oxide. (Sodium oxide, Na_2O, has a similar formula but does not have a common name.)
2. (a) The four kinds of oxides are acidic oxides, basic oxides, amphoteric oxides and neutral oxides.
   (b)

Similarities	Differences
1. All contain oxygen. 2. Except for neutral oxides, all form salts.	1. Some are oxides of metals whereas others are oxides of non-metals. 2. Some are solids, others are liquids or gases. 3. Some are soluble in water whereas others are insoluble.

3. (a) $SO_3(g) + H_2O(l) \longrightarrow H_2SO_4(aq)$ [sulfuric acid]
   (b) $P_4O_{10}(g) + 6H_2O(l) \longrightarrow 4H_3PO_4(aq)$ [phosphoric acid]
4. Gallium oxide is an amphoteric oxide.

(page 246)

Mystery Clue

Silicon(IV) oxide is an acidic oxide. As the sludge was alkaline, silicon(IV) oxide would react with the alkalis to reduce the pH of the sludge.

(page 247)

Mystery Clue

Aluminium oxide Al_2O_3. Calcium oxide CaO. Sodium oxide Na_2O. Aluminium oxide is amphoteric; the other two are basic oxides.

Notes for Teachers

Health risks of sulfur dioxide and sulfites
Sulfur dioxide (E220) and sodium sulfite (E221) are used as preservatives in foods in some foods and drinks. However, they can cause health problems for some people who consume foods and drinks containing these substances. Both can trigger asthma in certain individuals. In America they have been banned from most fruits and vegetables, because a number of people died from asthma attacks after eating food preserved with sulfites.

Teaching pointers

16.4 How is Neutralisation Applied in Daily Life? (page 248)

1. If taught in class time, teachers might first test the pH of some compost to show that it is acidic (using the method in Additional Experiment 1B in Chapter 15). Get the class to name plants that should grow well in soil containing compost.
2. Show students several brands of antacids and get them to read the labels and identify the active ingredients.
3. Exercise 16.2A in the Theory Workbook looks at the alkaline effect of toothpaste. To see this effect, dip a piece of pH paper in vinegar, and then place it on top of some toothpaste. The colour of the pH paper should change as the alkali in the toothpaste neutralises the acid in the vinegar.

(page 248)

Mystery Clue

These substances would react with alkalis in the sludge. For example, magnesium nitrate reacts with sodium hydroxide as shown in the equation:

$Mg(NO_3)_2(aq) + 2NaOH(aq) \longrightarrow 2Mg(OH)_2(s) + 2NaNO_3(aq)$

Chemistry in Society (page 249)

'Jeans City' and Pollution

Factories tend to discharge wastewater without treating it in order to save costs. The government in Singapore has strict guidelines on the treatment and discharge of industrial wastewater. According to these guidelines, acidic waste may be neutralised with slaked lime $Ca(OH)_2$, caustic soda NaOH or soda ash Na_2CO_3. Alkaline waste can be neutralised with sulfuric acid or hydrochloric acid.

Instead of alum, iron(II) sulfate in alkaline conditions can also be used to remove the pollutants from dyeing wastewater to form iron(II) hydroxide.

Exercise

1. They do so because this can save on costs associated with wastewater treatment, such as purchasing and maintenance of equipment for wastewater treatment.

   There could also be little enforcement for wastewater treatment and thus wastewater treatment does not seem necessary.

2. (a) The crops and livestock cannot obtain water from the river — their main source of water.
   The people are unable to wash their laundry using water from the river.

   (b) Without water for the crops and livestock and being unable to use the water for other purposes, the people would be forced to move to elsewhere. It becomes harder for the factory to employ workers living at nearer areas and thus may need to incur a higher cost in employing workers.

   The people living in communities may also bring charges against the factory and high costs would be incurred for compensation, which could be better spent on wastewater treatment facilities.

(page 249)

Mystery Clue

– Heavy metals such as lead are toxic and so are a danger for plant life and fish.
– The sludge does not need to be completely neutralised to be safe for plant and animal life. (Refer to Figure 15.39 in the Textbook for examples of substances we use that are alkaline but not hazardous.)

Skills Practice (page 250)

1. (a) Some antacids are solids (tablets or powder) whereas others are liquids.
   (b) They contain different active ingredients. For example, 'Alka-Seltzer' is sold as solid tablets with sodium hydrogencarbonate as the active ingredient.
2. $Al(OH)_3(s) + 3HCl(aq) \longrightarrow AlCl_3(aq) + 3H_2O(l)$
   $MgCO_3(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$
   $NaHCO_3(s) + HCl(aq) \longrightarrow NaCl(aq) + CO_2(g) + H_2O(l)$

Notes for Teachers

Notes on antacids

- Antacids are usually hydroxides, carbonates or sodium hydrogencarbonate.
- Some stomach medicines contain both an antacid and a pain reliever. For example, 'Alka-Seltzer' contains sodium hydrogencarbonate (antacid) and aspirin (pain reliever).
- Sodium hydrogencarbonate is the fastest acting antacid as it is water soluble. However, it can be absorbed into the blood and upset the balance of sodium in the body.
- Calcium and aluminium compounds tend to cause constipation. Magnesium compounds are a laxative. Thus some brands of antacids consist of mixtures of these compounds to balance the problems.

Teaching pointers

16.5 What are Salts (page 250)

1. The idea of an acid salt is not required in the 'O' Level syllabus.
2. Salts are ionic compounds. You may want to revise the naming of compounds. Refer to Section 4.3 on pages 56 and Section 6.3 on page 89 of the Textbook.
3. Other examples of salts and their uses are:
   - ammonium chloride, NH_4Cl, is used in zinc-carbon electrical cells.
   - potassium nitrate, KNO_3, is used as gunpowder which is a mixture of potassium nitrate, sulfur and carbon.
   - sports drinks which contain salts such as sodium chloride, potassium chloride, magnesium carbonate, sodium citrate (salt of citric acid) and calcium lactate (salt of lactic acid). Get students to look at the labels on some sports drinks and identify familiar salts.
4. Students need to know the solubility of salts in water. You may want to take a few salts and demonstrate the solubility of these salts in water.
5. In the preparation of the insoluble salt, barium sulfate discussed in Figure 16.15 on page 252 of the Textbook, ask students to suggest other possible sulfate reagents such as potassium sulfate, ammonium sulfate and even sulfuric acid. As most barium compounds are insoluble in water, barium nitrate and barium chloride are the only two barium reagents to use.
6. For the preparation of soluble salts using metals and insoluble bases or carbonates, emphasise that the presence of excess solid reagent in the reaction container indicates that the reaction is complete and the solution contains no more acid. Thus, an indicator is not needed. You may demonstrate how the apparatus is set up and the preparation carried out by referring to Figure 16.16 on page 253 of the Textbook.

7. To obtain solid salts, the solution of a salt is not normally evaporated to dryness. This is to prevent the solid from jumping out of the evaporating basin. Also, some salts decompose on heating.
8. Having isolated crystals of a salt from a solution, these crystals may be washed with a little water before being squeezed between sheets of filter paper. This removes the surface solution from the crystals together with any impurities in this solution.
9. In the preparation of a salt from an acid and an alkali, ensure that students understand the reason why an indicator must be used. Compare this method with the other methods of preparation which do not require the use of an indicator.
10. In Experiment 16.2 of the Practical Workbook, students prepare a salt using the titration method. As this is the first time that students are carrying out a titration, it is useful for you to demonstrate how the apparatus is set up and a titration is carried out. (For more on the titration technique, refer to pages 27–28 of the Practical Workbook.)
11. In Experiment 16.3 of the Practical Workbook, students plan and carry out an investigation to prepare a soluble salt by reacting an acid with a metal, metal oxide/hydroxide or metal carbonate.

Chemistry Inquiry (page 255)

How Would You Prepare Silver Chloride?

Group Discussion

1. Any other soluble metal chlorides, such as potassium chloride, calcium(II) chloride, zinc chloride and iron(II) chloride.
2. $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$
3. Refer to 'Preparation of insoluble salts' on page 252 of the Textbook.

Skills Practice (page 255)

1. Metals that are unsuitable are those located at the top of the reactivity series, such as potassium and sodium.
2. The presence of excess insoluble reactant at the bottom of the beaker tells us the reaction is complete, for example, the presence of excess zinc powder in Figure 16.16 on page 253 of the Textbook.
3. The substances are zinc oxide, zinc carbonate, zinc metal and zinc hydroxide.
4. **(a)** I – copper chloride, $CuCl_2$ II – barium sulfate, $BaSO_4$
   III – sodium nitrate, $NaNO_3$ IV – calcium nitrate, $Ca(NO_3)_2$
   V – lead sulfate, $PbSO_4$
   (b) III – sodium nitrate, $NaNO_3$
   (c) II – barium sulfate, $BaSO_4$
   (d) I: $CuO(s) + 2HCl(aq) \longrightarrow CuCl_2(aq) + H_2O(l)$
   II: $Ba(NO_3)_2(aq) + Na_2SO_4(aq) \longrightarrow BaSO_4(s) + 2NaNO_3(aq)$
   III: $NaOH(aq) + HNO_3(aq) \longrightarrow NaNO_3(aq) + H_2O(l)$
   IV: $CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$
   V: $H_2SO_4(aq) + Pb(NO_3)_2(aq) \longrightarrow PbSO_4(s) + 2HNO_3(aq)$
5. **(a)** To ensure all the acid reacts.
   (b) By filtration.
   (c) To dissolve the solid faster.

16 Chapter Review

Self-Management

Misconception Analysis (page 256)

1. **True** This is the definition of neutralisation (used at 'O' Level Chemistry). For example, hydrochloric acid reacts with sodium hydroxide solution to form the salt, sodium chloride and water only.

2. **False** Carbonates react with acids to form a salt, water and carbon dioxide. A base reacts with an acid to form a salt and water only.

3. **True** An alkali has a pH > 7. As an acid neutralises an alkali, the pH of the solution decreases until it reaches 7.

4. **False** Amphoteric oxides are metallic oxides. For example, aluminium oxide and zinc oxide.

5. **False** Some salts are insoluble in water. For example, all carbonates are insoluble except those of sodium, potassium and ammonium.

6. **False** Most salts contain a metal part. An example is sodium chloride. But ammonium salts, such as ammonium chloride, contain the ammonium ion which is not a metal ion.

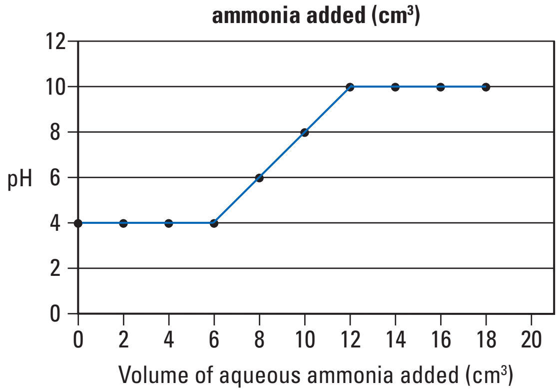
7. **True** As acids and alkalis are colourless solutions, the use of the titration method with an indicator is the only way to tell when neutralisation is complete.

Practice

Structured Questions (page 257–258)

1. (a) An alkali
   (b) Neutralisation reaction
   (c) $KOH(aq) + HCl(aq) \longrightarrow KCl(aq) + H_2O(l)$
   (d) Potassium chloride, KCl
   (e) $H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$

2. (a) Aqueous ammonia is ammonia gas that is dissolved in water.
   (b) **A graph of pH against volume of aqueous ammonia added (cm³)**



   (c) (i) pH = 4
   (ii) The soil is weakly acidic.
   (iii) pH = 10
   (iv) 9 cm³

3. (a) (i) Dilute hydrochloric acid
   (ii) pH ~ 1.5
   (b) (i) The antacid tablet contains a base that neutralises the acid. Therefore, pH increases as the neutralisation occurs.
   (ii) $Al(OH)_3(s) + HCl(aq) \longrightarrow AlCl_3(aq) + 3H_2O(l)$

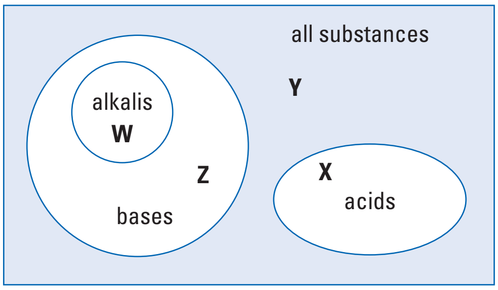
4. (a) (i) Aqueous sodium hydroxide and nitric acid
   (ii) Sodium hydroxide and nitric acid are both soluble in water so their solutions can be put into a pipette and a burette.
   (b) (i) Aqueous lead(II) nitrate and aqueous potassium iodide
   (ii) Lead(II) iodide is insoluble in water and can be separated by filtration from all the other reactants and products which are soluble in water.

5. (a) $B_2O_3(s) + 3H_2O(l) \longrightarrow 2H_3BO_3(aq)$
   (b) Boron is a non-metal as its oxide reacts with water to form an acid.
   (c) Na_3BO_3.
   $H_3BO_3(aq) + 3NaOH(aq) \longrightarrow Na_3BO_3(aq) + 3H_2O(l)$

6. (a) until no more will dissolve: This makes sure all the acid has reacted.
   filter the mixture: This removes unreacted copper(II) carbonate
   about half its volume: This removes water so that a hot saturated solution is obtained.
   filtrate to cool: This allows crystals to form as the solution cools.
   Do not heat the crystals: The crystals will decompose if heated.
   (b) Carbon dioxide gas.
   Bubble the gas through limewater. If the gas is carbon dioxide, a white precipitate is formed.
   (c) Copper(II) oxide, copper(II) hydroxide
   (d) The powder has a larger surface area than the lumps. This results in more frequent collisions with particles of the acid, leading to a faster reaction.

7. (a) Acid is produced by the bacteria feeding on the food particles in the mouth.
   (b) At 10.30 a.m., the student is eating a snack.
   At 4.00 p.m., the student is having a tea break.
   (c) The student is brushing his/her teeth. As toothpaste is slightly alkaline, the pH rises.
   (d) The student does not brush his/her teeth around these times.

8. (a) The litmus solution changes from blue to red.
   (b) Litmus solution is needed to indicate when all the sodium hydroxide (in the evaporating dish) has been neutralised.
   (c) The solution is heated to evaporate the water.
   (d) $2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$

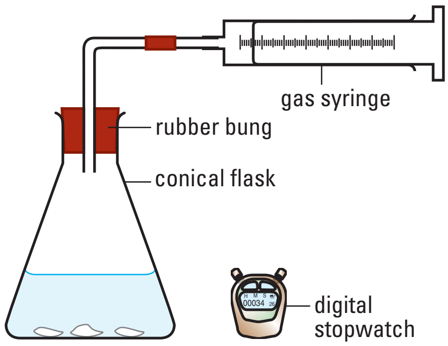
9. 

Free Response Questions (page 267)

1. Responses may include the following points:
   - Give three examples of the use of neutralisation in daily life.
   - Elaborate on one of these applications, e.g. antacid tablets and the treatment of indigestion.
     – The purpose of antacids is to neutralise stomach acid.
     – Give examples of compounds found in antacids.
     – Include one balanced equation.

2. Responses may include the following points:
   - Place dilute hydrochloric acid in a burette clamped to a retort stand.
   - Measure a known volume of potassium hydroxide solution using the measuring cylinder and place it in a beaker.
   - Add a few drops of indicator solution to the potassium hydroxide in the beaker.
   - Slowly add the acid from the burette to the beaker until the indicator just changes colour.
   - Repeat the experiment, adding the same volumes of acid and alkali without using the indicator.
   - Pour some of the neutral, colourless solution of potassium chloride into an evaporating dish. Set up the heating apparatus (burner, tripod and gauze). Evaporate about 2/3 of the solution. Leave the dish to cool for potassium chloride crystals to form.
   - Filter the potassium chloride crystals and dry them by squeezing them between sheets of filter paper.

3. Step 1: Add 24.3 g of magnesium ribbon into a conical flask
   Step 2: Connect a glass tube to a gas syringe and insert the tube into a rubber stopper
   Step 3: Pour excess ethanoic acid into the conical flask and quickly stopper the flask
   Step 4: Take readings at 10 seconds interval from the gas syringe and plot a graph of total volume of gas evolved against time



Extension (page 259)

Science and Medicine

(a) Antacids are usually sodium hydrogencarbonate and the hydroxides or carbonates of aluminium, magnesium and calcium. Aspirin is sometimes included as a pain reliever (it may be listed on a label as salicylate or acetylsalicylic acid).
(b) Examples of advantages and disadvantages:
   – Solids, in the form of tablets, are very convenient as they are portable.
   – Tablets are the slowest acting form of antacids.
   – Many tablets consist of insoluble ingredients so cannot be dissolved in water.
   – Liquids (solutions or suspensions) act the fastest as you don't have to wait for them to dissolve.
   – Many liquid antacids contain sodium hydrogencarbonate. However, this antacid can be harmful to people on a low-sodium diet.

Additional Teaching Material

Additional Exercise 1: What was the Question?

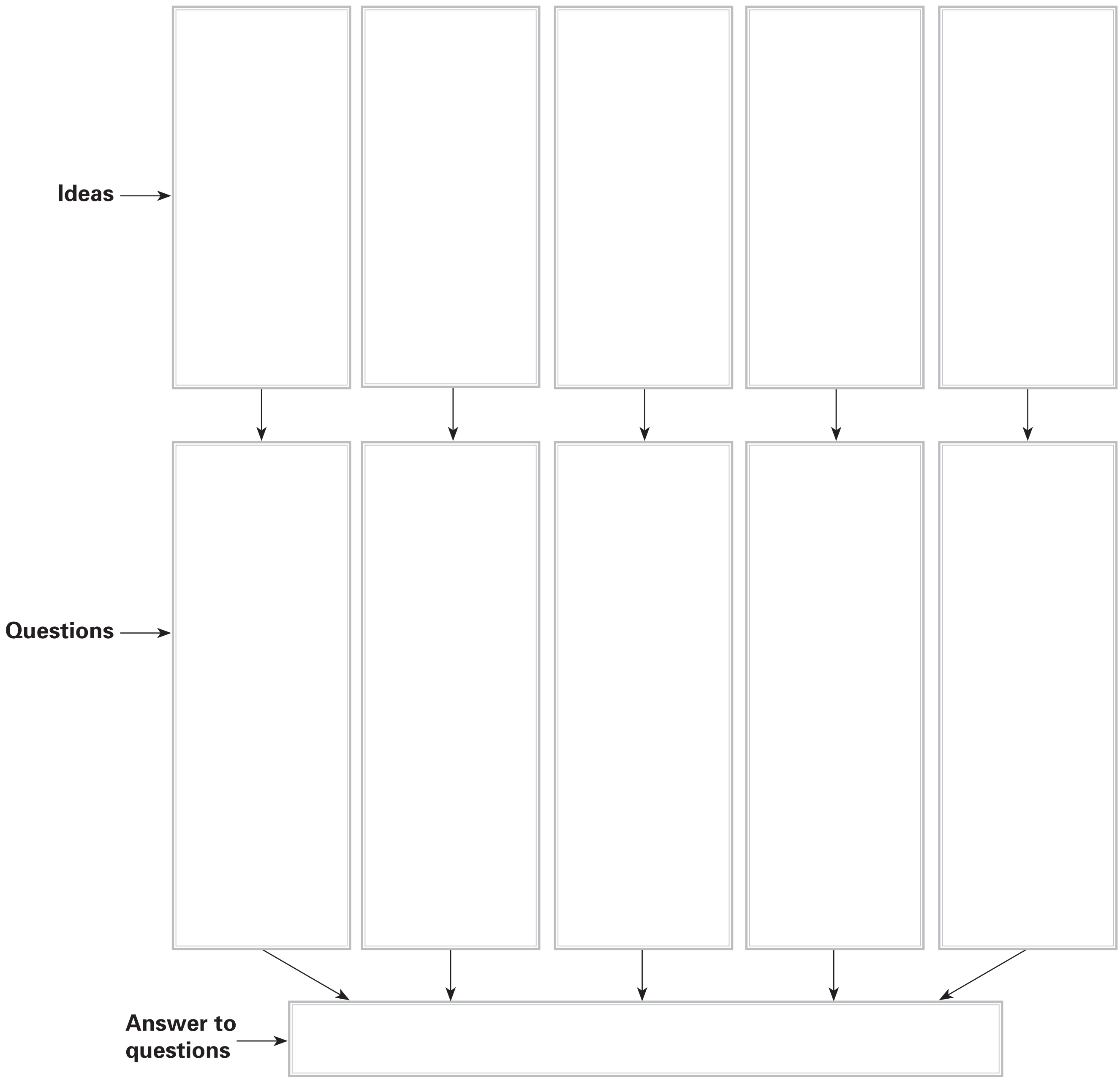
Objective

- To think of as many questions as possible for a given answer

Key Competency

CIT: Elaborating, generating ideas, inferring

A There is a chemistry problem. The final answer to the problem is zinc sulfate. Think of as many questions as possible for which the answer is zinc sulfate. You can do this by discussing with other students in a small group. Use the graphic organiser below to do this.



Answers

Additional Exercise 1:

Ideas	Making a salt	Making a salt	Making a salt	Name of salt from given formula	Soluble and insoluble salts
Questions	What salt is produced when dilute sulfuric acid reacts with zinc metal?	What salt is produced when dilute sulfuric acid reacts with zinc oxide?	What salt is produced when dilute sulfuric acid reacts with zinc carbonate?	What is the name of the salt with the formula $ZnSO_4$?	What is the name of a soluble zinc salt?
Answer to questions	Zinc sulfate				

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