# The Acidic Environment

## 1. Indicators were identified with the observation that the colour of some flowers depends on soil composition.

### 1.1 Perform a first-hand investigation to prepare and test a natural indicator.

**1.1.1**

(a) Define the term indicator.

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(b) Identify three commercial indicators used in the science laboratory.

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(c) Identify two naturally occurring substances that can be used as an indicator.

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(d) How are these substances treated in order to use them as indicators?

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**1.1.2** During this course you performed a first-hand investigation to prepare and test a natural indicator.

(a) Identify a substance you used to prepare a natural indicator.

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(b) Outline the method you used to make and test this indicator.

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(c) Use a table to report the results you obtained from this investigation.

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(d) Draw a conclusion as to the suitability of the substance you tested for use as an indicator.

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(e) Discuss the reliability of your investigation.

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(f) Identify appropriate equipment you could use to determine the pH at which the indicator you tested changed colour.

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**1.2 Identify data and choose resources to gather information about the colour changes of a range of indicators.**

**1.2.1** Identify the chemicals you used in the laboratory to gather information about the colour changes of a range of indicators.

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**1.2.2** State a conclusion that you were able to draw based on the results you observed.

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**1.2.3** Identify one risk factor that you should consider when carrying out this investigation.

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**1.3 Identify that indicators such as litmus, phenolphthalein, methyl orange and bromothymol blue can be used to determine the acidic or basic nature of a material over a range, and that the range is identified by change in indicator colour.**

**1.3.1** Litmus indicator can be obtained as a solution, or impregnated on strips of paper called litmus paper. It can be purchased as red litmus and as blue litmus.

(a) What will you observe when red litmus paper is placed in water?

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(b) What will you observe when blue litmus paper is placed in water?

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(c) What will you observe when red litmus paper is placed in dilute acid?

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(d) What will you observe when red and blue litmus are both placed in dilute acid?

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(e) Can you use red litmus alone to test whether a substance is acidic, basic or neutral?

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**1.3.2** The following table provides information about the colour changes of different commercial indicators at different pHs. Use this information to answer the questions below.

| Indicator | Colour in acid | Colour in base |
|---|---|---|
| Phenolphthalein | Colourless (below pH = 8.3) | Red (above pH = 10.0) |
| Bromothymol blue | Yellow (below pH = 6.0) | Blue (above pH = 7.6) |
| Methyl orange | Red (below pH = 3.1) | Yellow (above pH = 4.4) |

(a) Deduce the pH range during which methyl orange changes colour.

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(b) Water has a pH of 7. Are any of the above solutions suitable for testing whether a substance is neutral? Explain.

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(c) You are given three solutions labelled A, B and C. You are told that one has a pH of 5.5, another has a pH of 8.0 and the third has a pH of 10.3. Describe how you could use one of more of the indicators in the table to distinguish the two solutions.

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**1.3.3** Universal indicator consists of a mixture or dyes, so it can produce a range of colours at different pHs. The table below shows the colour of universal indicator over a range of pH values.

| pH | 1-4 | 5 | 6 | 7 | 8 | 9 | 10-11 |
|---|---|---|---|---|---|---|---|
| Colour | Red | Orange | Yellow | Green | Blue | Purple | Violet |

Indicate the colour you would expect universal indicator to change to if placed in the chemicals listed.

(a) concentrated sulfuric acid .....

(b) water .....

(c) concentrated sodium hydroxide .....

## 1.4 Classify common substances as acidic, basic or neutral.

**1.4.1** Identify three methods you could use to find out whether common substances are acidic, basic or neutral.

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**1.4.2** Complete the following table to indicate whether each of the following common substances is acidic, basic or neutral.

| Chemical | Formula | Acid/base/neutral | Home use |
|---|---|---|---|
| Acetic (ethanoic) acid | $CH_3COOH$ | | |
| Ethanol | | | |
| Sodium hydrogen carbonate | | | |
| Magnesium sulfate | | Slightly basic | Epsom salts – for constipation |
| Hydrochloric acid | | | |
| Sodium hydroxide | | | |

**1.5 Solve problems by applying information about the colour changes of indicators to classify some household substances as acidic, neutral or basic.**

**1.5.1**

(a) Identify a potential problem with using indicators to test the pH of green detergent.

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(b) How could you overcome this problem?

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**1.5.2** A group of Year 12 students tested some plants to see if they would be good indicators. Their results are shown in the following table. Answer the questions below based on this table.

| Plant | Original colour | Colour in vinegar | Colour in bicarbonate of soda |
|---|---|---|---|
| Red rose petals | Red | Pink | Green |
| Red geranium petals | Red | Orange | Yellow |
| Marigold petals | Yellow | Yellow | Yellow |
| Nasturtium petals | Orange | Yellow | Yellow |
| Red cabbage leaf | Purple | Pink | Green |
| Spinach leaf | Green | Yellow-green | Yellow-green |

(a) Analyse these results to indicate which of the plants tested would be useful as indicators. Justify your choice.

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(b) Predict the colour produced if red rose petal indicator is added to:

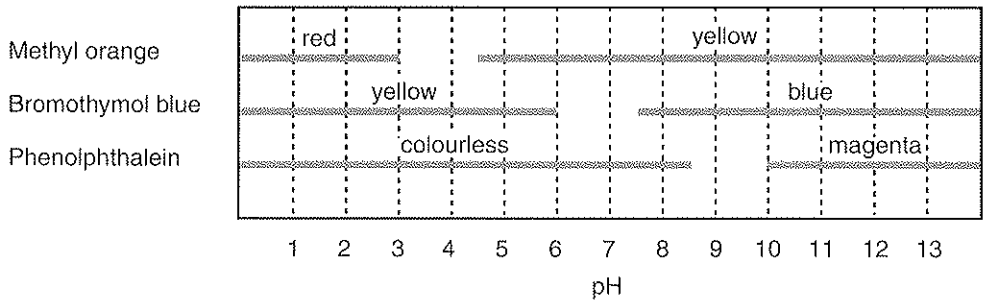
(i) dilute sulfuric acid .....

(ii) dilute sodium hydroxide .....

(iii) lemon juice .....

(iv) dishwasher detergent .....

**1.5.3** The following chart shows the colour ranges for the indicators methyl orange, bromothymol blue and phenolphthalein.




(a) Deduce the possible pH of a chemical that is yellow with methyl orange, blue with bromothymol blue and colourless with phenolphthalein.

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(b) Deduce the possible pH of a solution that is yellow with both methyl orange and bromothymol blue.

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(c) Predict the colour of hydrochloric acid with each of these indicators.

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## 1.6 Identify and describe some everyday uses of indicators including the testing of soil acidity/basicity.

**1.6.1** Describe the use of indicators in testing soil.

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**1.6.2** Describe two other everyday uses of indicators.

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**2. While we usually think of the air around us as neutral, the atmosphere naturally contains acidic oxides of carbon, nitrogen and sulfur. The concentrations of these acidic oxides have been increasing since the Industrial Revolution.**

**2.1 Identify oxides of non-metals which act as acids and describe the conditions under which they act as acids.**

**2.1.1** Identify oxides which act as acids and describe the conditions under which they act as acids.

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**2.1.2** Use equations to show oxides of sulfur and carbon dissolving in water to form acid.

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**2.1.3** Identify two oxides of non-metals that are only slightly soluble in water and thus form neutral solutions.

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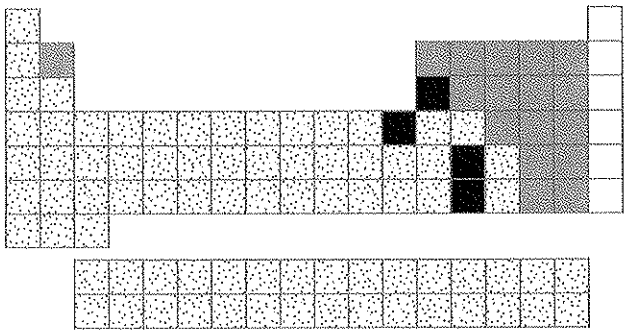
**2.2 Analyse the position of these non-metals in the Periodic Table and outline the relationship between position of elements in the Periodic Table and acidity/basicity of oxides.**

**2.2.1** Complete the key in the following Periodic Table to show which elements form acidic oxides, basic oxides, amphoteric oxides and which do not form any oxides.



Key

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**2.2.2** Complete the following general rules:

Oxides of non-metals are ..... oxides.

Oxides of metals are ..... oxides.

**2.2.3**

(a) Identify two ways we could test an oxide to see if it is acidic or basic.

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(b) Use an equation to show the neutralisation of the acidic oxide, sulfur dioxide, with the base sodium hydroxide.

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**2.2.4**

(a) Metals form basic oxides. Basic oxides will dissolve in water to form an hydroxide.

Complete the following equation to illustrate this.

Magnesium oxide + water $\rightarrow$ .....

$MgO(s) + H_2O(l) \rightarrow$ .....

(b) Basic oxides react with acids to form water and a salt. Use an equation to show the reaction of basic magnesium oxide with hydrochloric acid.

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## 2.3 Define Le Châtelier's principle.

**2.3.1** Complete the following to summarise the characteristics of a reversible system that has reached equilibrium.

(a) It is a ..... system – no matter or energy enters or leaves the system.

(b) Macroscopic properties (e.g. state, colour, temperature and pressure) stay ..... .

(c) Concentrations of reactants and products stay ..... .

(d) Continual ..... change occurs between reactants and products.

(e) The rate of forward reaction = rate of ..... reaction.

**2.3.2** Define Le Châtelier's principle.

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**2.4 Identify factors which can affect the equilibrium in a reversible reaction.**

**2.4.1** Identify factors which can affect the equilibrium in a reversible reaction.

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**2.4.2** Outline any effect of a catalyst on an equilibrium reaction.

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**2.5 Describe the solubility of carbon dioxide in water under various conditions as an equilibrium process and explain in terms of Le Châtelier's principle.**

**2.5.1** Describe the solubility of carbon dioxide in water as an equilibrium reaction.

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**2.5.2**

(a) Describe the effect of changes in concentration (of reactants or products) on the solubility of carbon dioxide in water using Le Châtelier's principle.

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(b) Relate these changes to Le Châtelier's principle.

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**2.5.3** Use Le Châtelier's principle to describe the effect of changes in pressure on the equilibrium produced when carbon dioxide dissolves in water in a closed system.

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**2.5.4** Explain the changes in solubility of carbon dioxide with changes in temperature.

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**2.6 Calculate volumes of gases given masses of some substances in reactions, and calculate masses of substances given gaseous volumes, in reactions involving gases at 0°C and 100 kPa or 25°C and 100 kPa.**

**2.6.1** Define the following terms:

(a) mole

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(b) molar mass

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(c) molar volume

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**2.6.2** The molar volume of any gas is always the same for any particular temperature and pressure. Use the data table at the back of this book to complete the following statement:

At 100 kPa pressure, one mole of any gas will occupy ..... at 0°C and ..... at 25°C.

**2.6.3** State formulas that may be used for calculating the number of moles of a substance.

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**2.6.4** Complete the following table of calculations:

| Mass of gas | Number of moles of gas | Volume of gas at 0°C | Volume of gas at 25°C |
|---|---|---|---|
| 44.01 g of carbon dioxide | | | |
| 44.01 g of sulfur dioxide | | | |
| | 5.00 moles of carbon dioxide | | |
| | 5.00 moles of sulfur dioxide | | |
| | | 232.55 L of $CO_2$ | |

**2.6.5** Sulfur dioxide is produced by the smelting of copper sulfide ores.

(a) Write a symbolic equation to show the smelting of copper sulfide.

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(b) Calculate the number of moles present in 980 kg of copper sulfide.

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(c) Calculate the number of moles of sulfur dioxide produced by the smelting of 980 kg of copper sulfide.

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(d) What volume would this mass of sulfur dioxide occupy at 25°C and 100 kPa?

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## 2.7 Identify data, plan and perform a first-hand investigation to decarbonate soft drink and gather data to measure the mass changes involved and calculate the volume of gas released at 25°C and 100 kPa.

**2.7.1** In class you performed a first-hand investigation that involved decarbonating a soft drink.

(a) Outline the meaning of decarbonation.

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(b) Describe the method you used to decarbonate the soft drink.

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(c) Justify the need to set up a control in this experiment.

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(d) Identify variables that you controlled.

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(e) Assess the reliability of your results.

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**2.7.2** A group of students carried out the decarbonation of a bottle of soft drink and found that the mass of the container decreases by 2.5 g. Assume all of the weight loss is due to carbon dioxide escaping.

(a) How many moles of carbon dioxide would have been lost from the soft drink?

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(b) What volume would this mass of carbon dioxide occupy at 25°C?

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**2.7.3** A group of students tested the pH of distilled water a number of times with a probe. They found that the pH of the distilled water was less than 7 and that the pH decreased on cold days. Explain these observations.

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## 2.8 Identify natural and industrial sources of sulfur dioxide and oxides of nitrogen.

### 2.8.1

(a) Recall the properties of sulfur dioxide.

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(b) Outline the health risks associated with sulfur dioxide.

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(c) Outline uses of sulfur dioxide.

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(d) Outline environmental risks associated with the release of sulfur dioxide into the atmosphere.

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**2.8.2** Identify the main natural and industrial sources of sulfur dioxide in the atmosphere.

Natural sources of sulfur dioxide:

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Industrial sources of sulfur dioxide:

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**2.8.3** There are a number of oxides of nitrogen, all of which are harmful to the respiratory system, causing decreased lung function, susceptibility to respiratory infections and increased sensitivity to asthma triggers. Complete the following table to summarise the main oxides of nitrogen.

| Names and formula | Appearance and acidity | Natural sources | Industrial sources |
|---|---|---|---|
| Nitrogen dioxide, Nitrogen(IV) oxide ($NO_2$) | | | |
| Dinitrogen monoxide | | | |
| Nitrogen monoxide | | | |

## 2.9 Describe, using equations, examples of chemical reactions which release sulfur dioxide and chemical reactions which release oxides of nitrogen.

**2.9.1** Describe, using equations, examples of chemical reactions which release sulfur dioxide.

**2.9.2** Describe, using equations, examples of chemical reactions which release oxides of nitrogen.

## 2.10 Explain the formation and effects of acid rain.

**2.10.1** Explain the formation of acid rain.

**2.10.2** Complete the following table to explain the effects of acid rain.

| Efects of acid rain | Explanation |
|---|---|
| Causes defoliation and stunts growth of plants and some sensitive ones, e.g. spruce trees, are destroyed. | |
| Animal life is affected. | |
| Corrosion and decay of metals, buildings, stone structures, paint and statues. | |
| Sulfate particles have affected peoples' health. | |

## 2.11 Assess the evidence which indicates increases in atmospheric concentration of oxides of sulfur and nitrogen.

**2.11.1** Assess the evidence which indicates increases in atmospheric concentration of oxides of sulfur and nitrogen.

**2.12 Analyse information from secondary sources to summarise the industrial origins of sulfur dioxide and oxides of nitrogen and evaluate reasons for concern about their release into the environment.**

**2.12.1** Summarise the industrial origins of:

(a) sulfur dioxide

(b) oxides of nitrogen

**2.12.2** Evaluate reasons for concern about the release into the environment of sulfur dioxide and oxides of nitrogen.

## 3. Acids occur in many foods, drinks and even within our stomachs.

**3.1 Solve problems and perform a first-hand investigation to use pH meters/probes and indicators to distinguish between acidic, basic and neutral chemicals.**

**3.1.1** You carried out a first-hand investigation to use pH meters/probes and indicators to distinguish between acidic, basic and neutral chemicals.

(a) Describe the method you used.

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(b) Outline any advantage of using a pH meter or a probe instead of an indicator such as methyl orange or phenolphthalein.

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**3.2 Define acids as proton donors and describe the ionisation of acids in water.**

**3.2.1** An acid can be described as a proton donor. Justify this definition.

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**3.2.2** Draw a diagram of a hydrogen ion.

**3.2.3** Describe the ionisation of sulfuric acid in water.

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**3.2.4**

(a) Use a diagram to show the structure of an hydronium ion.

(b) Explain the formation of an hydronium ion.

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## 3.3 Identify acids including acetic (ethanoic), citric (2-hydroxypropane-1,2,3-tricarboxylic), hydrochloric and sulfuric acid.

**3.3.1** Complete the following table to summarise information about the listed acids.

| Name | Formula | Found in/used for |
|---|---|---|
| Acetic (ethanoic) acid | $CH_3COOH$ | |
| Citric acid (2-hydroxypropane-1,2,3-tricarboxylic acid) | | |
| | HCl | |
| Sulfuric acid | | |

## 3.4 Identify data, gather and process information from secondary sources to identify examples of naturally occurring acids and bases and their chemical composition.

**3.4.1** Complete the following table to summarise the names and chemical composition of some naturally occurring acids.

| Common substance | Acid present | Chemical composition |
|---|---|---|
| Citric juice, e.g. oranges and lemons | | Organic compounds |
| Vinegar | | |
| Stomach acid | | |
| Sour milk, yoghurt | Lactic acid | $CH_3CHOHCOOH$ |
| Ant stings | Methanoic acid | HCOOH |

**3.4.2** A base can be described as a proton acceptor. Justify this definition.

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**3.4.3** Distinguish between a base and an alkali.

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**3.4.4** Complete the following table to summarise the names and chemical composition of some naturally occurring and synthetic bases.

| Common substance | Base present | Natural or synthetic | Chemical composition |
|---|---|---|---|
| Limewater | | Synthetic | |
| Bicarbonate of soda | | Natural | |
| Lime | | Synthetic | |
| Drain and oven cleaner | | Synthetic | |
| Household cleaners (with ammonia) | Ammonium hydroxide | Synthetic | |

## 3.5 Describe the use of the pH scale in comparing acids and bases.

**3.5.1** Describe the pH scale.

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**3.5.2** Indicate the approximate pH of the following common substances.

| Substance | Approximate pH |
|---|---|
| 0.1 mol $L^{-1}$ HCl | |
| Stomach acid (HCl) | |
| Lemon juice | |
| Vinegar | |
| Soft drink (contains carbonic acid) | |
| Wine | |
| Urine | |
| Pure water | |
| Human blood | |
| Sea water | |
| Toothpaste | |
| Dishwasher detergent | |
| Oven and drain cleaner | |

## 3.6 Describe acids and their solutions with the appropriate use of the terms strong, weak, concentrated and dilute.

**3.6.1** Distinguish between a strong acid and a weak acid.

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**3.6.2** Strength is not the same as concentration. Distinguish between a concentrated acid and a dilute acid.

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**3.6.3** Use diagrams to model the difference between the terms strong, weak, concentrated and dilute when applied to solutions of acids.

**3.7 Plan and perform a first-hand investigation to measure the pH of identical concentrations of strong and weak acids.**

**3.7.1** During this topic you performed a first-hand investigation to measure the pH of identical concentrations of strong and weak acids.

(a) Identify which acids you used and their concentrations.

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(b) Identify the equipment you used to measure the pH of these acids.

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(c) Describe and justify conclusions made from your data.

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**3.8 Gather and process information from secondary sources to write ionic equations to represent the ionisation of acids.**

**3.8.1** Write ionic equations to show the ionisation of the following acids:

(a) sulfuric acid

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(b) phosphoric acid

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(c) hydrobromic acid

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(d) acetic acid

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**3.9 Use available evidence to model the molecular nature of acids and simulate the ionisation of strong and weak acids.**

**3.9.1** Acids are described as both molecular and ionic. Account for the use of these two terms when referring to acids.

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**3.9.2**

(a) Outline the method you used to model the molecular nature of acids.

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(b) Outline the method you used to simulate the ionisation of strong and weak acids.

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**3.10 Identify pH as $-\log_{10}[H^+]$ and explain that a change in pH of 1 means a tenfold change in $[H^+]$.**

**3.10.1**

(a) Mathematically, the pH of a solution is given by: $pH = -\log_{10}[H^+]$.

Explain what is meant by $[H^+]$.

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(b) Calculate the pH when the hydrogen ion concentration is:

(i) 0.1 .....

(ii) 0.01 .....

(iii) 0.001 .....

(c) Complete the following statements.

(i) Being a logarithmic scale, if the pH changes by one, the hydrogen ion changes by ..... .

(ii) If the pH changes by two, then the hydrogen ion concentration changes by ..... .

**3.10.2**

(a) Write an equation to show the ionisation of water.

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(b) Identify the concentration of hydrogen ions and hydroxide ions in pure water at 25°C.

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(c) Define the ionic product.

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(d) Explain the significance of the fact that the product of the hydrogen ion concentration and the hydroxide ion concentration ( $[H^+] \times [OH^-]$ ) is constant.

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**3.10.3**

(a) In an aqueous solution, if $[H^+] = 10^{-6}$, calculate $[OH^-]$.

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(b) The hydroxide ion concentration of water is $10^{-4}$, calculate the hydrogen ion concentration.

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(c) In a sodium chloride solution, $[H^+] = 10^{-7}$. For this solution, calculate:

(i) $[OH^-]$ .....

(ii) pH .....

(iii) pOH .....

**3.10.4** In an aqueous solution, pH + pOH = 14. Calculate:

(a) pH when pOH = 7 .....

(b) pOH when pH = 3 .....

(c) pH when pOH = 3 .....

**3.11 Compare the relative strengths of equal concentrations of citric, acetic and hydrochloric acids and explain in terms of the degree of ionisation of their molecules.**

**3.11.1** Identify two methods we could use to measure the relative strengths of equal concentrations of a number of acids.

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**3.11.2** Explain why strong acids are better conductors of electricity than weak acids of the same concentration.

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**3.11.3** The following table compares the strengths of three dilute acids when their concentrations are the same.

| Acid | Concentration | pH | Strength | Degree of ionisation |
|---|---|---|---|---|
| Citric | 0.1 mol $L^{-1}$ | 2.1 | Weak | 8% |
| Acetic (ethanoic) | 0.1 mol $L^{-1}$ | 2.9 | Weak | 1.3% |
| Hydrochloric | 0.1 mol $L^{-1}$ | 1 | Strong | 100% |

(a) Which of these three acidic solutions would be the best conductor of electric current. Explain.

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(b) Which of these three acidic solutions would have the lowest pH. Explain.

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**3.12 Describe the difference between a strong and a weak acid in terms of an equilibrium between the intact molecule and its ions.**

**3.12.1**

(a) Describe the difference between a strong and a weak acid in terms of an equilibrium between the intact molecule and its ions.

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(b) Explain why strong acids have a lower pH than weak acids of the same concentration.

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**3.13 Process information from secondary sources to calculate pH of strong acids given appropriate hydrogen ion concentrations.**

**3.13.1** Calculate the pH of the following solutions.

(a) A 0.1 mol $L^{-1}$ solution of hydrochloric acid.

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(b) A 0.1 mol $L^{-1}$ solution of sulfuric acid if it completely ionises.

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(c) A 0.1 mol $L^{-1}$ solution of carbonic acid if only 8% ionises.

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(d) A 0.1 mol $L^{-1}$ solution of sodium hydroxide.

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**3.13.2** Calculate the pH of solutions with the following hydrogen ion concentrations:

(a) $5.5 \times 10^{-2}$ mol $L^{-1}$ .....

(b) $8.6 \times 10^{-5}$ mol $L^{-1}$ .....

(c) $1.8 \times 10^{-3}$ mol $L^{-1}$ .....

**3.14 Gather and process information from secondary sources to explain the use of acids as food additives.**

**3.14.1**

(a) The following additives are frequently found in commercial foods:

sulfur dioxide, benzoic acid, acetic (ethanoic) acid, lactic acid and citric acid.

What do these substances have in common?

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(b) Account for the use of acids as food additives.

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(c) State one problem with the addition of chemical preservatives to foods.

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## 4. Because of the prevalence and importance of acids, they have been used and studied for hundreds of years. Over time, the definitions of acid and base have been refined.

### 4.1 Gather and process information from secondary sources to trace developments in understanding and describing acid/base reactions.

**4.1.1**

(a) Acknowledge resources you used to obtain information about developments in understanding and describing acid/base reactions.

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(b) Identify the advantage of using scaffolds to collect research information.

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### 4.2 Outline the historical development of ideas about acids including those of Lavoisier, Davy and Arrhenius.

**4.2.1** Complete the following passage to summarise the contribution of Lavoisier to the development of understanding of acids.

**Antoine Lavoisier** (1743-1794) was a French chemist. He is sometimes called the father of chemistry. Lavoisier showed the importance of accurate measurements, he demonstrated that the atmosphere contains ..... and that combustion involves reaction with ..... and wrote the first modern chemistry textbook.

His experiments on combustion led him to believe that acids were made of two substances, one of which was ..... . He believed that ..... was present in all acids and it caused their acidity.

**4.2.2** Complete the following passage to summarise the contribution of Davy to the development of understanding of acids.

**Humphry Davy** (1778-1829) was an English chemist famous for his experiments on electrolysis and for his discovery of a number of elements.

In 1810, he demonstrated that muriatic acid ( ..... acid) was a compound of hydrogen and chlorine and did not contain ..... .

He observed that metals could displace ..... from acids and concluded that acids contain ..... . By 1830 at least 10 more acids that did not contain ..... had been discovered, including HF, HI, HBr, HCN and $H_2S$. So Davy concluded that all acids contain ..... .

**4.2.3** Complete the following passage to summarise the contribution of Arrhenius to the development of understanding of acids.

In 1884, a Swedish chemist named **Svante Arrhenius** (1859-1927) suggested that acids are neutral substances that dissolve in water and dissociate to give positive ..... ..... and a ..... ion. Positive ions are called cations and negative ions are called anions. He used this idea to define acids and bases.

According to Arrhenius' theory:

An acid is a substance that ionises in water to produce ..... ions ($H^+$) as the only ..... ions.

A base is a substance that ionises in water to produce ..... ions ($OH^-$) as the only ..... ions.

**4.2.4** The theories of Lavoisier and Davy were based on practical observations, whereas that of Arrhenius was based on theoretical ideas. Discuss this statement.

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**4.2.5** Outline three limitations of Arrhenius' definition of acids and bases.

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## 4.3 Outline the Brönsted-Lowry theory of acids and bases.

**4.3.1** Who were Brönsted and Lowry?

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**4.3.2** Define the following terms according to the Brönsted-Lowry theory of acids and bases.

(a) an acid

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(b) a base

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(c) an acid-base reaction

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**4.3.3** The reaction of hydrogen chloride gas with ammonia gas,

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

is classified as an acid-base reaction according to the Brönsted-Lowry theory, but not according to Arrhenius' theory of acids and bases.

Explain this statement.

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**4.3.4** State three advantages of the Brönsted-Lowry theory of acids and bases over Arrhenius' theory.

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**4.3.5** Complete the following table to compare the Arrhenius model with the Brönsted-Lowry model of acids and bases.

| Model | Definition of acid | Definition of base |
|---|---|---|
| Arrhenius | | Hydroxide ion producer in water |
| Brönsted–Lowry | Hydrogen ion (proton) donor | |

**4.4 Describe the relationship between an acid and its conjugate base and a base and its conjugate acid.**

**4.4.1** Explain what is meant by a conjugate pair.

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**4.4.2** Complete the following table to show acid/base pairs composed of a conjugate acid and a conjugate base.

| Conjugate acid | Conjugate base |
|---|---|
| $H_3O^+$ | |
| | $Cl^-$ |
| $CH_3COOH$ | |
| | $HSO_4^-$ |
| $HSO_4^-$ | |
| | $OH^-$ |

**4.5 Identify conjugate acid/base pairs.**

**4.5.1** According to the Brönsted-Lowry theory, when an acid/base neutralisation reaction occurs, the products are another acid and base so two acid/base pairs are present in each reaction. Discuss this statement with reference to the reaction between hydrogen chloride gas and ammonia gas.

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**4.5.2** Complete the following equation and label the acid/base pairs.

$CH_3COOH(l) + H_2O(l) \rightleftharpoons$

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## 4.6 Choose equipment and perform a first-hand investigation to identify the pH of a range of salt solutions.

**4.6.1** During this course, you performed a first-hand investigation to identify the pH of a range of salt solutions.

(a) Describe how you measured the pH of each solution tested.

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(b) Use the following table to show the results you obtained for four solutions that you studied.

| Name of salt | Formula | Observation of colour change or pH reading | Acidic/basic or neutral |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

(c) Could you use your results to rank the solutions tested in order of strength of solution (from most acidic to most basic)?

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**4.6.2** Use diagrams to model the following solutions:

(a) a neutral salt such as sodium chloride

(b) an acidic salt such as ammonium chloride

(c) a basic salt such as sodium acetate

**4.6.3** In the question above you used diagrams to model the composition of solutions.

(a) Discuss advantages of using these models.

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(b) Discuss limitations of these models.

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## 4.7 Identify a range of salts which form acidic, basic or neutral solutions and explain their acidic, neutral or basic nature.

**4.7.1** Identify each of the following salts as acidic, basic or neutral.

| Name of salt | Acidic/basic/neutral |
|---|---|
| Ammonium sulfate | |
| Lithium chloride | |
| Ammonium carbonate | |
| Calcium acetate | |
| Ammonium nitrate | |
| Calcium carbonate | |
| Sodium sulfate | |

**4.7.2** Deduce whether each of the following salts is acidic, basic or neutral. Justify your decision.

(a) potassium carbonate

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(b) sodium nitrate

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(c) ammonium chloride

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**4.8 Identify amphiprotic substances and construct equations to describe their behaviour in acidic and basic solutions.**

**4.8.1**

(a) Some substances such as water are said to be amphiprotic. Explain the meaning of this term and use equations to show that water is amphiprotic.

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(b) Distinguish between the terms amphiprotic and amphoteric.

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**4.8.2** Use equations to show that the hydrogen sulfate ion ($HSO_4^-$) is amphiprotic.

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**4.9 Identify neutralisation as a proton transfer reaction which is exothermic.**

**4.9.1**

(a) Recall what is meant by a neutralisation reaction.

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(b) What observation have you made that allows you to determine whether neutralisation reactions are endothermic or exothermic.

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(c) Write an equation for the neutralisation of sodium hydroxide and hydrochloric acid.

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(d) Write the equation in (c) to show all the ions present.

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(e) Write the same equation as an ionic equation.

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**4.9.2** Neutralisation is a proton transfer reaction.

(a) Rewrite the ionic equation for neutralisation to show the two acid/base conjugate pairs involved in this reaction.

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(b) Describe the proton transfer that occurs in neutralisation reactions.

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**4.10 Describe the correct technique for conducting titrations and preparation of standard solutions.**

**4.10.1** Define the following terms:

(a) titration

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(b) quantitative volumetric analysis

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(c) standard solution

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(d) equivalence point

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(e) end point

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**4.10.2**

(a) Distinguish between a primary standard and a secondary standard.

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(b) List the requirements for a primary standard.

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(c) Identify the most common primary standards.

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**4.10.3** Use a flow chart to show how you would make up a standard solution for use in a titration. In your answer include a diagram of any specialised equipment necessary.

**4.10.4** Complete the following table by sketching the titration curves indicated.

| Strong base and strong acid | Strong base and weak acid |
|---|---|
| Weak base and strong acid | Weak base and weak acid |

**4.10.5** Complete the following table to show whether the acids and bases listed are strong or weak.

| Acid | Strong or weak | Base | Strong or weak |
|---|---|---|---|
| HCl | | $Mg(OH)_2$ | |
| H2$SO_4$ | | $NH_4OH$ | |
| $H_2CO_3$ | | NaOH | |
| $CH_3COOH$ | | KOH | |

**4.10.6** Complete the following table to identify a suitable indicator to use with each of the following acid-base combinations and justify your choice.

| Acid | Base | Suitable indicator | Justification |
|---|---|---|---|
| HCl | KOH | | |
| $H_2SO_4$ | $NH_4OH$ | | |
| $H_2CO_3$ | NaOH | | |
| $CH_3COOH$ | $Ca(OH)_2$ | | |

**4.10.7** A pipette and a burette are used during titrations.

(a) Identify each of these pieces of apparatus by means of diagrams.

(b) Complete the following table to summarise the use of a pipette and a burette.

| | Pipette | Burette |
|---|---|---|
| Function | | |
| Procedure for washing during a titration | | |
| Volume measured | | |

**4.10.8**

(a) During a titration, the acid and base are usually mixed in a flask. This flask is rinsed with water only. It is not rinsed with the solution to be placed in it. Explain.

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(b) How many times should you carry out a titration?

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**4.10.9**

(a) List the steps to be carried out when performing a titration.

(b) Use a diagram to show the equipment you would use for a titration.

## 4.11 Perform a first-hand investigation and solve problems using titrations and including the preparation of standard solutions, and use available evidence to quantitatively and qualitatively describe the reaction between selected acids and bases.

**4.11.1** Outline the titrations you performed as first-hand investigations.

**4.11.2** Why is sodium hydroxide always used as a secondary standard and never prepared as a primary standard?

**4.11.3** Write relevant equations and calculate the volume of 0.15 mol $L^{-1}$ sodium hydroxide that will just neutralise:

(a) 25.0 ml of 0.06 mol $L^{-1}$ hydrochloric acid

(b) 25.0 mL of 0.06 mol $L^{-1}$ sulfuric acid

**4.11.4** A standard solution of anhydrous sodium carbonate was prepared by dissolving 3.25 g in distilled water and then making it up to 250 mL in a volumetric flask.

(a) Calculate the:

(i) molar mass of anhydrous sodium carbonate ($Na_2CO_3$)

(ii) number of moles in 3.25 g of anhydrous sodium carbonate

(iii) molarity (in mol $L^{-1}$) of the sodium carbonate solution

(b) This standard sodium carbonate solution was then used to standardise hydrochloric acid. A pipette was used to measure 25.0 mL of the sodium carbonate solution. This was placed in a conical flask with methyl orange as indicator. The sodium carbonate solution was neutralised by 11.8 mL of the hydrochloric acid. Calculate the following, showing all working.

(i) moles of sodium carbonate used in the titration

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(ii) moles of HCl reacting

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(iii) concentration of the hydrochloric acid

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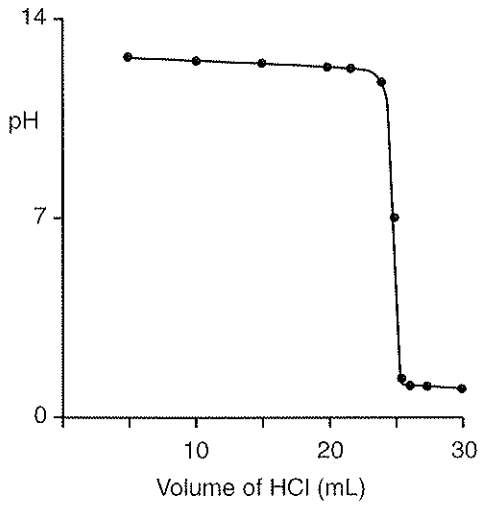
**4.11.5** Using computer technology, a group of students perform a titration using 25 mL 0.1 mol $L^{-1}$ sodium hydroxide against a solution of hydrochloric acid and they print out the following titration curve.




Account for the shape of this graph.

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**4.12 Perform a first-hand investigation to determine the concentration of a domestic acidic substance using computer-based technologies.**

**4.12.1** Describe the first-hand investigation you performed to determine the concentration of a commercial acidic substance. In your answer:

(a) Identify the commercial substance being investigated.

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(b) Identify the standard you used in the titration and describe its preparation.

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(c) Justify your use of this standard.

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(d) Describe the steps in the procedure you used to determine the concentration of the commercial substance.

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(e) List the main steps in your calculations.

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(f) Describe any problems you encountered in your investigation and suggest ways to overcome these problems.

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**4.12.2** Outline the technology you used to carry out a first-hand investigation of the concentration of a domestic acidic substance.

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**4.12.3** Acids, alkalis and salts ionise in water and the presence of ions allows them to conduct an electric current. Some students used a conductivity probe to investigate the effect of increasing the concentration of sodium chloride on the ability of a solution to conduct an electric current. Their results were as follows:

| Drops of salt added | Relative conductivity (volts) |
|---|---|
| 0 | 0.00 |
| 1 | 0.06 |
| 2 | 0.12 |
| 3 | 0.17 |
| 4 | 0.21 |
| 5 | 0.28 |
| 6 | 0.33 |
| 7 | 0.37 |
| 8 | 0.46 |
| 9 | 0.51 |

(a) Graph these results.

(b) Draw a conclusion based on these results.

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(c) If the salt magnesium chloride ($MgCl_2$) was used (with the same concentrations) in place of sodium chloride, would you expect similar results?

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**4.13 Analyse information from secondary sources to assess the use of neutralisation reactions as a safety measure or to minimise damage in accidents or chemical spills.**

**4.13.1** Use the following table to explain two safety rules which apply to using acids.

| Identify | Describe | Explain |
|---|---|---|
| | | |
| | | |

**4.13.2** Assess the use of neutralisation reactions in acid spills.

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**4.14 Qualitatively describe the effect of buffers with reference to a specific example in a natural system.**

**4.14.1**

(a) Define what is meant by a buffer and identify two examples.

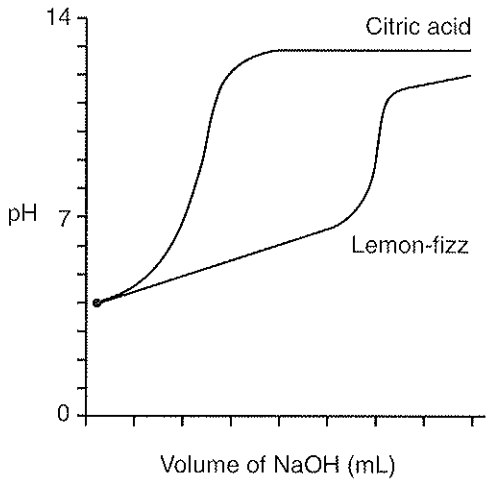
(b) Describe the action of a buffer in a natural system. (Include equations.)

(c) Explain the importance of buffers in organisms.

**4.14.2** A commercial brand of lemonade, called Lemon-fizz, uses a citric acid-sodium citrate buffer solution rather than straight citric acid.

A group of students decided to compare this buffer with unbuffered citric acid by titrating both solutions with sodium hydroxide.

The following graphs show their results.




(a) Outline one trend evident in both graphs.

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(b) Outline one difference between the two graphs.

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(c) From these results, draw conclusions about the action of a buffer.

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## 5. Esterification is a naturally occurring process which can be performed in the laboratory.

### 5.1 Describe the differences between the alkanol and alkanoic acid functional groups in carbon compounds.

**5.1.1** Alkanols and alkanoic acids are two homologous series of organic compounds. Use the following table to distinguish between these two series.

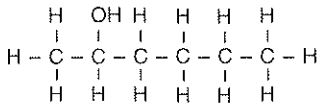
| | Alkanols | Alkanoic acids |
|---|---|---|
| Functional group | | |
| General formula | | |
| Polarity | | |
| Other | | |

**5.1.2** Complete the following table to summarise the formulas of the first eight alkanoic acids in the series.

| Name | Structural formula | Molecular formula |
|---|---|---|
| Methanoic acid | | HCOOH |
| | | $CH_3COOH$ |
| Propanoic acid | | |
| | | $C_3H_7COOH$ |
| Pentanoic acid | | |
| | | $C_5H_{11}COOH$ |
| Heptanoic acid | | |
| | | $C_8H_{15}COOH$ |

**5.1.3** Identify each of the following compounds.

(a)



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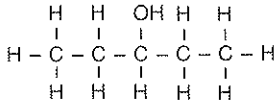
(b)



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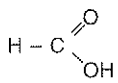
(c)



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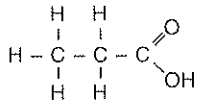
(d)



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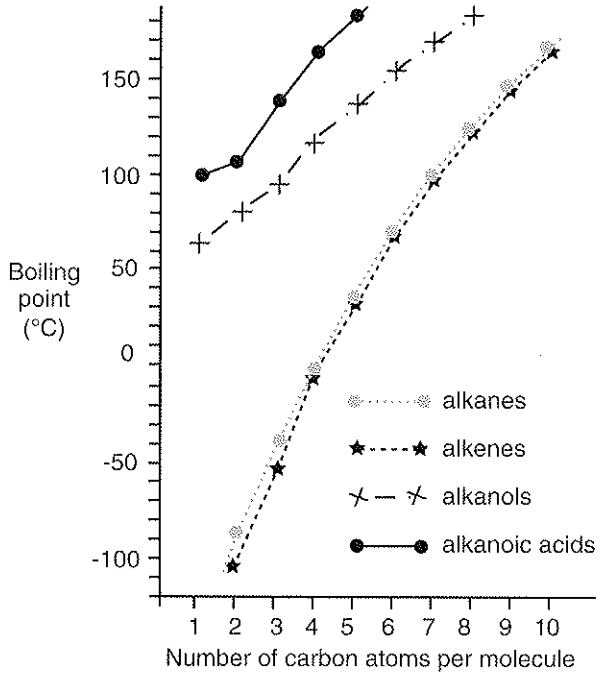
**5.2 Explain the difference in melting point and boiling point caused by straight-chained alkanoic acid and straight-chained primary alkanol structures.**

**5.2.1** The following graphs compare the boiling points of homologous groups of carbon compounds. Describe two trends in these graphs.




**5.2.2** Explain the difference in melting point and boiling point of straight-chained alkanoic acids compared to straight-chained primary alkanol structures.

**5.3 Identify esterification as the reaction between an acid and an alkanol and describe, using equations, examples of esterification.**

**5.3.1** Define esterification.

**5.3.2** Esterification is described as a condensation reaction. Explain.

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**5.3.3** Complete the following word equations to show examples of esterification.

(a) propanol + ethanoic acid $\rightleftharpoons$

(b) methanol + butanoic acid $\rightleftharpoons$

(c) ethanol + propanoic acid $\rightleftharpoons$

(d) methanoic acid + octanol $\rightleftharpoons$

## 5.4 Identify the IUPAC nomenclature for describing the esters produced by reactions of straight-chained alkanoic acids from C1 to C8 and straight-chained primary alkanols from C1 to C8.

**5.4.1** Complete the following close passage.

Esters are ..... compounds which are made by the reaction of an ..... and an alkanoic ..... The general formula of an ester is RCOOR′ where R and R′ are carbon chains.

Short chain esters are volatile ..... . As the carbon chain becomes longer, the esters become less ..... , more oily and viscous. Long chain esters are soft solids or waxes.

**5.4.2** Complete the following table naming esters and the alkanol and acid used to manufacture these esters and showing all structural formulas.

| Alkanol | Alkanoic acid | Ester |
|---|---|---|
| Ethanol | Methanoic acid | Ethyl methanoate |
| Propanol | Methanoic acid | |
| | | Butyl methanoate |
| | | Pentyl propanoate |
| Octanol | Ethanoic acid | |

**5.4.3** Revision: Complete the following table to summarise the homologous series of carbon compounds that you have studied in this course.

| Name of homologous series | Functional group | General formula | Name and formula of an example |
|---|---|---|---|
| Alkene | | | |
| Alkane | | | |
| Alkanol | | | |
| Alkanoic acid | | | |
| Ester | | | |

## 5.5 Describe the purpose of using acid, in esterification, for catalysis.

### 5.5.1

(a) What is meant by catalysis?

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(b) Describe the purpose of using acid as a catalyst in esterification.

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**5.6 Explain the need for refluxing during esterification.**

**5.6.1**

(a) Define reflux and explain the need for refluxing during esterification. Use a diagram in your answer.

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(b) Explain the movement of water through the condenser jacket.

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**5.7 Identify data, plan, select equipment and perform a first-hand investigation to prepare an ester using reflux.**

**5.7.1** During this module you performed a first-hand investigation in which you prepared an ester using reflux.

(a) Identify the reactants you used and the products formed.

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(b) Explain the need for reflux during this reaction.

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(c) Outline safety precautions necessary for this procedure.

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(d) How does the condenser differ in the processes of reflux and distillation?

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**5.8 Outline some examples of the occurrence, production and uses of esters.**

**5.8.1** Esters occur naturally in living things. Fats and oils are esters, and esters give perfume and taste to flowers and fruits. Esters tend to have strong flavours and odours, so they are manufactured for use as flavours and perfumes in processed foods and in cosmetics. They are also useful as solvents.

(a) Identify an ester used as nail polish remover.

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(b) Identify an ester manufactured to artificially flavour food.

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**5.9 Process information from secondary sources to identify and describe the uses of esters as flavours and perfumes in processed foods and cosmetics.**

**5.9.1** You have researched the uses of esters as flavours and perfumes in processed foods and cosmetics. Identify two esters you have researched and for each ester, state its name, formula and use.

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**Notes**