FACTFILE: GCSE CHEMISTRY: UNIT 1.8

Rewarding Learning

Acids, bases and salts

Learning outcomes

Students should be able to:

1.8.1 recall the colours of phenolphthalein and methyl orange in acidic, alkaline and neutral solutions;

1.8.2 recall the effect of acidic, alkaline and neutral solutions on indicator papers (red and blue litmus papers and universal indicator paper) and the use of a pH meter giving pH data to one decimal place;

1.8.3 interpret given data about universal indicator (colour/pH) to classify solutions as acidic, alkaline or neutral and to indicate the relative strengths of acidic and alkaline solutions, according to the following classification:

- pH 0–2 strong acid;
- pH 3–6 weak acid;
- pH 7 neutral;
- pH 8–11 weak alkali; and
- pH 12–14 strong alkali;

1.8.4 demonstrate knowledge and understanding that acids dissolve in water to produce hydrogen (H^+ (aq)) ions;

1.8.5 **recall that the higher the concentration of hydrogen ions in an acidic solution, the lower the pH;**

1.8.6 demonstrate knowledge and understanding that alkalis dissolve in water to produce hydroxide (OH^- (aq)) ions;

1.8.7 **demonstrate knowledge and understanding that strong acids and strong alkalis are completely ionised in water,** recall examples of strong acids (including hydrochloric acid, sulfuric acid and nitric acid) and recall examples of strong alkalis (including sodium hydroxide and potassium hydroxide); and

1.8.8 **demonstrate knowledge and understanding that weak acids and weak alkalis are partially ionised in water,** recall examples of weak acids (including ethanoic acid and carbonic acid) and recall examples of weak alkalis (including ammonia);

1.8.9 **explain the terms dilute and concentrated in terms of the amount of substances in solution**;

1.8.10 describe neutralisation as the reaction between the hydrogen ions in an acid and the hydroxide ions in an alkali to produce water **and recall the ionic equation as: H^+ (aq) + OH^- (aq) ⟶ H_2O(l);**

1.8.11 investigate the temperature change during neutralisation and understand that neutralisation reactions are exothermic (heat is given out);

1.8.12 recall that a base is a metal oxide or hydroxide which neutralises an acid to produce a salt and water and that an alkali is a soluble base;

1.8.13 demonstrate knowledge and understanding of and write observations on and equations for the general reactions of hydrochloric, sulfuric and nitric acids with:

- metals;
- bases;
- carbonates; and
- hydrogencarbonates;
- ammonia.

1.8.14 describe how to test for hydrogen gas: apply a lighted splint and a popping sound results;

1.8.15 describe how to test for carbon dioxide: limewater (calcium hydroxide solution) will change from colourless to milky if the test is positive.

1.8.16 demonstrate knowledge and understanding that a salt is a compound formed when some or all of the hydrogen ions in an acid are replaced by metal ions or ammonium ions;

1.8.17 demonstrate knowledge and understanding that most Group 1 (I), Group 2 (II), aluminium and zinc salts are white and if they dissolve in water they give colourless solutions and that transition metal salts are coloured;

1.8.18 demonstrate knowledge and understanding of how pure dry samples of soluble salts can be prepared by:

- adding excess insoluble substances to the acid;
- adding alkali to acid, or vice versa, in the presence of an indicator; and
- repeating without indicator or removing the indicator using charcoal (methods of drying to include placing in a desiccator or a low temperature oven or drying between two sheets of filter paper);

1.8.19 develop awareness of the importance of safety in the laboratory to assess potential risks, including the hazards associated with chemicals labelled with the GHS/CLP international chemical hazard labelling (including toxic, corrosive, flammable, explosive and caution).

Indicators

The effects of acid and alkali on litmus paper and other indicators is shown below.

	colour in acid	**colour in alkali**
Red litmus paper	red	blue
Blue litmus paper	red	blue

	colour in acid	colour in neutral	colour in alkali
Phenolphthalein	colourless	colourless	pink
Methyl orange	red	orange	yellow

An acid is a substance which dissolves in water producing hydrogen ions, H^+.

An alkali is a substance which dissolves in water producing hydroxide ions, OH^-

A strong acid is one which is fully ionised in water in other words, it releases the maximum possible number of hydrogen ions. Examples include: sulfuric acid (H_2SO_4), nitric acid (HNO_3), and hydrochloric acid (HCl). **A weak acid is one which is partially ionised in water**; examples include ethanoic acid and carbonic acid .

A strong alkali is one which fully ionises in water, in other words, it releases the maximum possible number of hydroxide ions. Examples include: sodium hydroxide (NaOH) and potassium hydroxide (KOH). **A weak alkali is one which is partially ionised in water**; for example ammonia solution (NH_3 (aq)).

Universal indicator comes in paper form or as a solution. The colour corresponds to a pH value which is linked to the strength of the acid or alkali. To find the pH , place one drop of the solution on pH paper and compare the colour to the pH colour chart.

A more accurate alternative is a pH meter, a digital device which records the pH to 1 decimal place.

pH	pH 0–2	pH 3–6	pH 7	pH 8–11	pH 12–14
classification	Strong acid	Weak acid	Neutral	Weak alkali	Strong alkali
Colour of pH paper	red	orange or yellow	green	green-blue or blue	dark blue or purple

A concentrated acid contains a large number of acid particles dissolved per unit volume

A dilute acid contains a small number of acid particles dissolved per unit volume

For an acid the pH is linked to the concentration of H^+ ions in the solution. The **higher** the **concentration** of hydrogen ions in an acidic solution, the **lower the pH**.

Dilute solutions are labelled with the hazard symbol 'caution' whereas more concentrated solutions are usually labelled 'corrosive'. Other hazard symbols you should remember are toxic, flammable and explosive.

Reactions of acids

Each acid reacts to produces its own salt:

Acid	Salt	Example
hydrochloric acid	chloride	sodium chloride
sulfuric acid	sulfate	copper(II) sulfate
nitric acid	nitrate	magnesium nitrate

A salt is the compound formed when some or all of the hydrogen ions of an acid are replaced by metal ions or ammonium ions.

1. Reaction with metals

The presence of hydrogen can be confirmed with a lighted splint; it will be put out with a popping sound as the hydrogen reacts with oxygen in the air ($2H_2 + O_2 \longrightarrow 2H_2O$).

metal + acid ⟶ salt + hydrogen

e.g magnesium + hydrochloric acid ⟶ magnesium chloride + hydrogen

$Mg + 2HCl \longrightarrow MgCl_2 + H_2$

Observation: Bubbles, metal disappears; if the metal is from Group II a colourless solution of the salt is formed, heat is released.

To test for the hydrogen gas produced, apply a lighted splint and there should be a pop.

2. Reaction with bases

The general equation for this reaction is:

base + acid ⟶ salt + water

A base is a metal oxide or hydroxide that neutralises an acid to produce a salt and water.
An alkali is a soluble base.

This is a neutralisation reaction. In a neutralisation reaction between an acid and an alkali (soluble base), the water is formed as the hydrogen ions and hydroxide ions combine:

$H^+ (aq) + OH^- (aq) \longrightarrow H_2O (l)$

The reaction is exothermic as heat is given out.

For example,

copper(II) oxide + sulfuric acid ⟶ copper(II) sulfate + water
$CuO + H_2SO_4 \longrightarrow CuSO_4 + H_2O$

Observation: black solid disappears and solution changes from colourless to blue

For example,

sodium hydroxide + hydrochloric acid ⟶ sodium chloride + water
$NaOH + HCl \longrightarrow NaCl + H_2O$

Observation: heat is released

3. Reaction with carbonates/hydrogencarbonates

acid + carbonate ⟶ salt + water + carbon dioxide
acid + hydrogencarbonate ⟶ salt + water + carbon dioxide

The presence of carbon dioxide can be confirmed by passing the bubbles of gas through colourless limewater, which will change to milky.

For example:

sodium carbonate + hydrochloric acid ⟶ sodium chloride + water + carbon dioxide

$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$

Observation: white solid disappears, colourless solution produced, heat released, bubbles

Preparation of salts

There are two methods of preparing salts

Method 1

Adding excess insoluble substance to the acid

1. Measure out a volume of acid (25 cm^3) using a measuring cylinder, and place in a conical flask
2. Warm gently, stir and add spatulas of the solid until some excess solid is left unreacted and lies on bottom of the beaker.
3. Filter off the excess insoluble reactant and collect the filtrate in an evaporating basin.
4. Heat the filtrate to evaporate to half volume and form a hot saturated solution.
   Leave to cool and crystallise.
5. Filter off the crystals.
6. Dry the crystals between two sheets of filter paper or in a low temperature oven or in a desiccator.

Method 2

Adding acid to alkali (or vice versa) in the presence of an indicator.

This general method is called a titration.

Both acid and alkali solutions are colourless, so an indicator must be used to determine when they are neutralised and the salt is produced. The general method involves measuring out 25.0cm^3 of acid using a pipette, adding indicator, and then adding alkali from a burette until the colour changes. The indicator can then be removed by heating with charcoal or the method can be repeated using no indicator and the same volume used of acid used. Then as usual, heat to evaporate and make the solution more concentrated, cool and crystallise, filter the crystals from solution and dry the crystals.

Revision Questions

1.

Copper(II) oxide reacts with sulfuric acid to form a solution of copper(II) sulfate in water.

(a) Explain why this reaction is a neutralisation reaction.

_____

_____ [2]

(b) What is the colour of copper(II) oxide?

_____ [1]

(c) What is the colour of the solution of copper(II) sulfate?

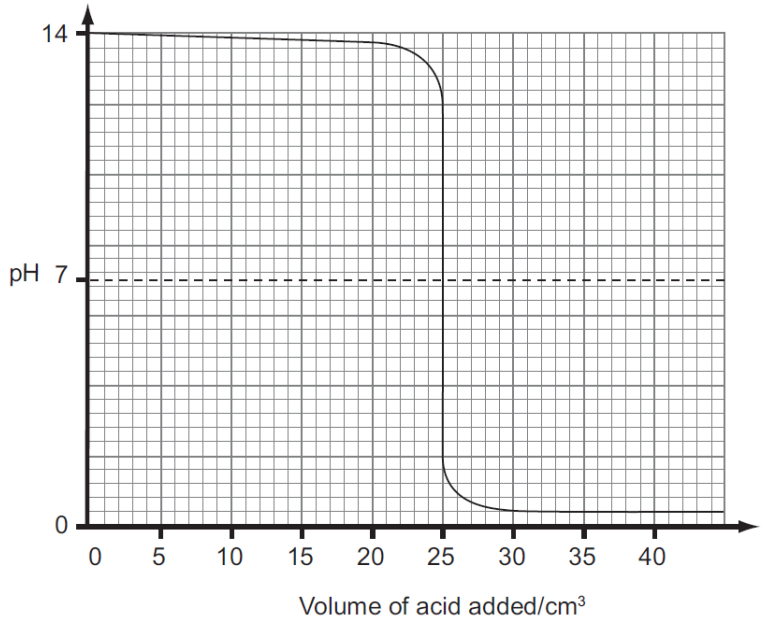
_____ [1]

(d) Write the formula of the ion which is always produced when an acid dissolves in water.

_____ [1]

2.

The pH changes during the reaction between sodium hydroxide and hydrochloric acid were measured using a pH meter. The following graph was produced.



(a) What was the pH value of the liquid in the flask at the start of the experiment?

_____ [1]

(b) What volume of acid was needed to cause a sudden drop in the pH value?

_____ [1]

(c) Explain why litmus paper could **not** be used instead of a pH meter for this experiment.

_____

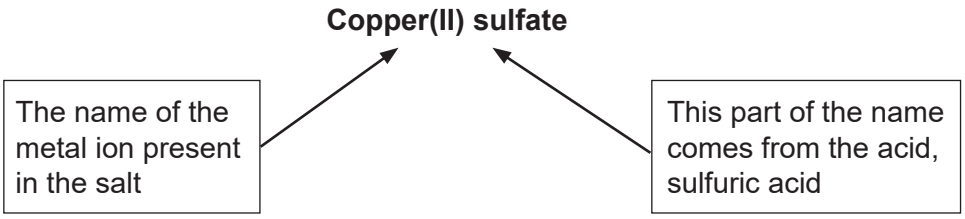
_____ [1]

(d) Complete the symbol equation for this reaction:

$$HCl + NaOH \longrightarrow \quad + \quad$$ [2]

3. Read the following information carefully.

Copper(II) oxide, a black solid, reacts with sulfuric acid and ethanoic acid to form two different salts. Salt is a general name given to one of the compounds formed when an acid is neutralised. The salt formed between copper(II) oxide and sulfuric acid is called copper(II) sulfate.



Name of acid	Name of salt produced when the acid reacts
hydrochloric acid	chloride
nitric acid	nitrate
sulfuric acid	sulfate
phosphoric acid	phosphate
ethanoic acid	ethanoate

(a) Name the salt formed when copper(II) oxide reacts with ethanoic acid.

_____ [1]

(b) What is the name given to the type of reaction between an acid and a base to form a salt and water only?

_____ [1]

(c) Write a balanced symbol equation for the reaction between copper(II) oxide and sulfuric acid.

_____ [2]

(d) Describe what you would observe when copper(II) oxide reacts with sulfuric acid.

_____

_____

_____ [2]

_____

4. Indicators can change colour in acid and alkaline solutions. Indicators can be made from plant material such as red cabbage.

The table below gives information about three different indicators. Use this information to answer the questions that follow.

Substance	Colour of universal indicator paper	Colour of red litmus paper	Colour of red cabbage solution	pH range
Hydrochloric acid	red	red	red	1-2
Sodium hydroxide	dark blue	blue	yellow	12-14
water	green	red	purple	7
ethanoic acid	orange	red	red	3-6

(i) Why is red litmus paper **not** a suitable indicator for testing pH?

_____

_____ [1]

(ii) Explain why red cabbage solution can be described as an indicator.

_____

_____

_____

_____ [2]

(iii) Why is universal indicator a better indicator than red cabbage solution for testing acids?

_____

_____

_____ [1]

5. A solution of 0.05 mol/dm^3 acid Y was tested using a pH meter and universal indicator paper. The results are recorded in the table below.

Test	Result
pH meter	pH = 3.03
Universal indicator	orange pH = 3

(i) Explain how the colour of universal indicator is used to give a pH value.

_____

_____ [1]

(ii) How do the results show that acid Y is a weak acid?

_____

_____ [1]

(iii) Give one example of a weak acid.

_____ [1]

(iv) Which property of the acid is measured in the units mol/dm^3? Circle the correct answer.

mass **volume** **concentration** **strength**

[1]

6.

(a) Calcium chloride solution may be prepared from solid calcium carbonate and dilute hydrochloric acid.

(i) Describe fully how a solution of calcium chloride may be prepared from solid calcium carbonate and dilute hydrochloric acid.

In this question, you will be assessed on using your written communication skills including the use of specialist science terms.

_____

_____

_____

_____

_____

_____

_____

_____ [6]

(ii) Write a balanced symbol equation for the reaction between calcium carbonate and hydrochloric acid.

_____ [3]

(iii) Describe the process of obtaining pure, dry crystals of hydrated calcium chloride from a solution of calcium chloride.

_____

_____

_____

_____

_____

_____

_____

_____ [3]

b) Calcium chloride may also be prepared by neutralising calcium hydroxide solution with dilute hydrochloric acid. 25.0 cm^3 of calcium hydroxide solution is placed in a conical flask with phenolphthalein indicator and hydrochloric acid is added.

(i) Write an **ionic equation** for the neutralisation reaction. Include state symbols.

_____ [3]

(ii) State the colour change of the indicator in this preparation.

From _____ to _____ [2]

(iii) What common name is used for calcium hydroxide solution?

_____ [1]

(c) A solution of 0.015 mol/dm³ hydrochloric acid was tested using a pH meter, red and blue litmus and universal indicator paper. The results are given below.

Test	Result
pH meter	1.82
red litmus	red
blue litmus	red
universal indicator paper	red

(i) Explain how the result with universal indicator may be converted into a pH value.

_____

_____ [1]

(ii) Explain why the result with red litmus is not conclusive for the presence of an acid.

_____

_____ [1]

(iii) Based on the results in the table, select **two** pieces of evidence which would suggest that hydrochloric acid is a strong acid. Explain your answer.

_____

_____

_____

_____ [2]