CHANGES IN ACIDITY

A TEACHERS' GUIDE

Overall picture of the Module
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NUFFIELD SCIENCE 13 TO 16



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OVERALL PICTURE OF THE MODULE

Most likely year: 4 or 5

Previous Module: Particles at work

Notes	Materials in this unit		
Taste; use of indicators; pH; stomach acidity 1–6	One **What is an acid?**		
Reactions with metals, oxides, hydroxides, and carbonates; word equations 8–10	Two **Reactions of acids**		SCISP *4*, 3.2
Acid properties can only be seen in certain solvents (particularly water) 11–14	Three **The importance of the solvent** NSS 7.24		SCISP *4*, 3.4
Using changes in temperature and pH to follow course of neutralization 15–17	Four **Neutralization**		SCISP *4*, 3.5, 3.10
Reaction used as summary; conductimetric titration 18, 19	Five **Barium hydroxide(aq) + sulphuric acid(aq)**		SCISP *4*, 3.7
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Effect of surface area, concentration, and temperature 22, 23	Seven **Factors affecting rate of corrosion** NSS 7.24		SCISP *4*, 3.8
Pickling; pH in the garden; sting treatment 7, 24–28	Eight **Desirable changes in acidity**	**Final questions**	

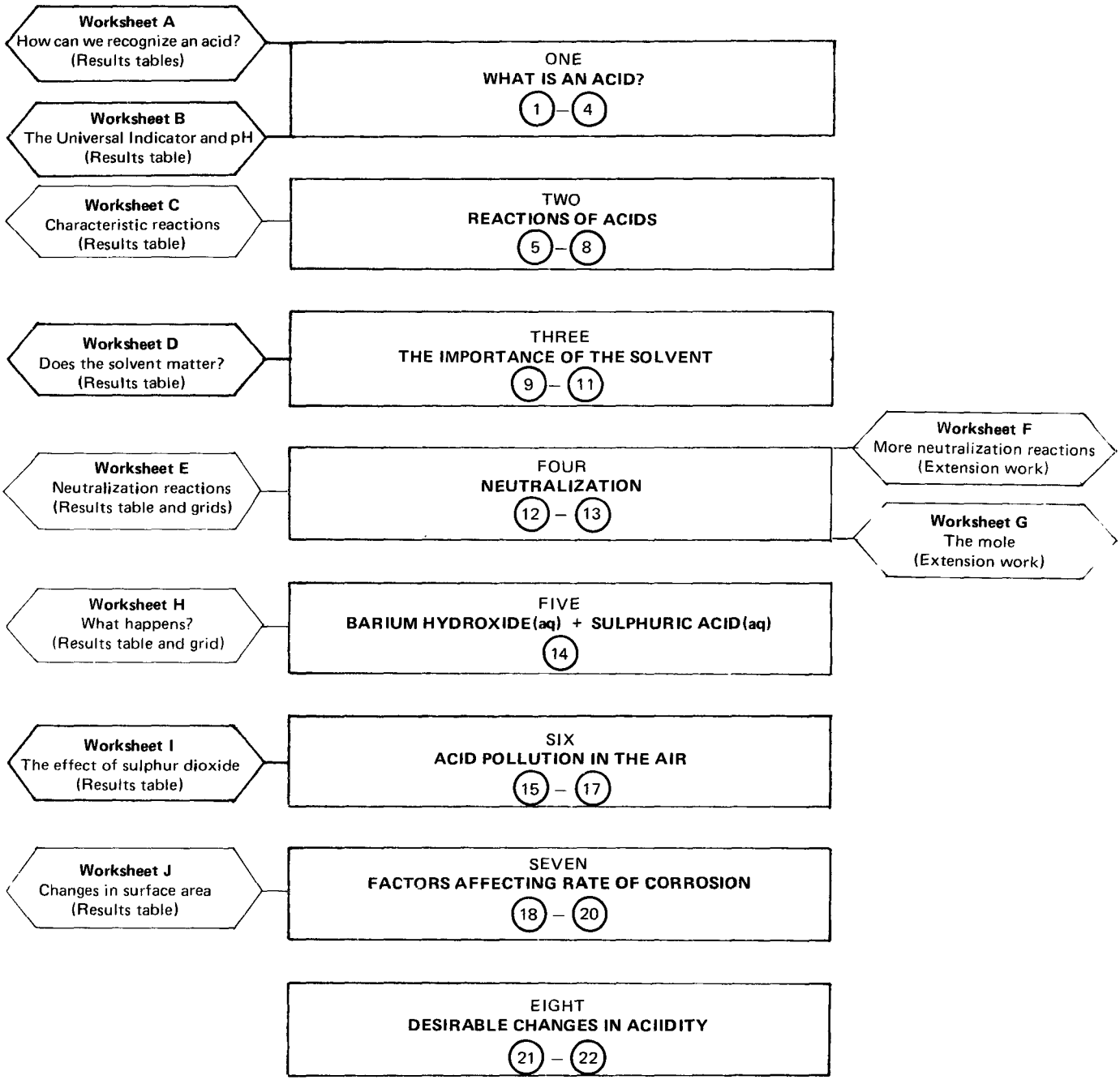
The numbers in the 'Notes' column refer to the 'Ideas' listed below.

IDEAS THAT MIGHT BE COVERED IN THE MODULE

(The difficulty rating is indicated by stars.)

* **1** Acids have a sharp taste.
* **2** Your stomach contains a weakly acidic solution.
* **3** Too much acid in the stomach causes indigestion.
* **4** Stomach powders – alkalis – remove the excess acidity.
* **5** Vegetable dyes are different colours in acidic and in alkaline solutions.
* **6** Universal Indicator and the pH scale.
* **7** We use acids for a variety of purposes in our homes.
* **8** Acids can be neutralized by reacting with metals, metal oxides, metal hydroxides, and metal carbonates.
* **9** All these reactions produce salts.
** **10** Word equations for these reactions.
* **11** Some acids only show their typical properties in solution in water.
* **12** Acids produce hydrogen at the cathode, on electrolysis.
** **13** Electrolysis of acids shows the presence of hydrogen ions which are not found in pure water.
*** **14** Acids dissolve in water to form the hydrated hydrogen ion, $H_3O^+(aq)$.
* **15** Neutralization is accompanied by a temperature rise.
** **16** Acid + alkali → salt + water.
*** **17** $H^+(aq)$ $[H_3O^+(aq)]$ + $OH^-(aq) \rightarrow H_2O(l)$ $[2H_2O(l)]$.
** **18** An understanding of the simple ionic particle picture for the reaction of barium hydroxide and sulphuric acid.
*** **19** Relating this to the changes in pH and conductivity of the reaction mixture during the course of the reaction.
* **20** Sulphur in hydrocarbon fuels gives rise to SO_2 pollution.
** **21** Sulphur dioxide forms an acidic solution in water and increases the rate of metal corrosion.
** **22** Increasing temperature increases the rate of reaction.
*** **23** The greater the surface area exposed to the acid, the faster the corrosion.
* **24** Enzymes are destroyed by acids.
* **25** Pickling preserves onions and red cabbage!
** **26** Addition of vinegar (increasing pH) is a useful way of preventing enzyme-controlled decomposition in foods.
* **27** pH of the soil can be controlled by adding peat or lime.
* **28** Wasp stings can be treated with vinegar (acid); bee stings with bicarbonate of soda (alkali).

SOME POSSIBLE ROUTES THROUGH THE MODULE



The circled numbers refer to the apparatus lists for each activity.

The more difficult Worksheets are shown on the right.

ORGANIZATION OF THE MATERIAL

This Module is intended to occupy eight double periods, or eleven hours.

Apparatus lists

These have been numbered consecutively throughout this *Guide*, thus: (2). Also, they have been designed so that they can be duplicated, cut out, and stuck on 5-inch × 3-inch record cards. In the case of some longer lists, a perforated line has been included. The list is intended to be folded or cut here and stuck on both sides of a card.

Worksheets

These can be duplicated in the numbers needed for the minority groups for which they are suitable. As indicated above, eight of the ten provided are for recording the results of experiments; two provide extension work for the more able pupils.

ABBREVIATIONS USED IN THIS GUIDE

PB *Pupils' book*
TG *Teachers' guide*
NSS Nuffield Secondary Science
SCISP Schools Council Integrated Science Project

Science Learning Centres
N13122

WHENEVER YOUR PUPILS ARE DOING PRACTICAL WORK THEY MUST WEAR SAFETY SPECTACLES.

ONE
WHAT IS AN ACID?

Pupils' book pages 1 to 4

The purpose of this chapter is to introduce the simple chemistry of acids. Pupils may have met some of the ideas in an earlier introductory science course, but as much practical work as possible has been included to provide an interesting and enjoyable beginning.

1 Acids have a special taste

It is important to pay particular attention to hygiene when pupils are tasting things. They usually enjoy this rare opportunity to 'taste a chemical', and some may 'get a taste for it', so make sure only a small quantity is available. Wooden swabs, cotton buds, or wooden splints should be used to pick up the citric acid crystals or any other acid-containing foodstuffs which may be available. Sterilize all containers.

2 How can we recognize an acid?

Vegetable dyes are used at first as indicators and they are seen to be different colours in acid solution, in water, and in solution X. (X is sodium hydroxide solution and at this stage it is deliberately not referred to as an alkaline solution. It is used here solely to demonstrate the colour changes which occur when indicators are used.) The shortcomings of vegetable dyes as indicators are then pointed out before chemical indicators are used. *Worksheet A* can be available for recording results.

3 The Universal Indicator and pH

Here pupils experience the colour changes of Universal Indicator by adding ammonia solution, in 0.5 cm^3 portions, to acetic acid solution. They see that ammonia removes acidity. At this point, solutions like ammonia and solution X can be referred to as 'alkaline solutions'. The solution of pH7 is shown to be 'neither acidic nor alkaline'. The terms 'neutral' and 'neutralization' are not introduced until Chapter Four. *Worksheet B* can be used for recording results.

4 Getting rid of stomach ache

Here pupils observe the effects of some everyday indigestion remedies upon 0.01M hydrochloric acid. No worksheet has been produced for this section in order to allow pupils the opportunity to demonstrate their own skills in recording results. They should have gained an idea of what is required, from using *Worksheets A* and *B* in the previous sections.

APPARATUS

Changes in acidity, Chapter One (1)

Section 1 'Acids have a special taste'

a Safety spectacles
b Sterilized wooden swabs, wooden splints, or cotton buds
c Citric acid crystals
d (Optional) acid-containing foods, *e.g.* oranges, lemons, grapefruit, rhubarb, etc.

Changes in acidity, Chapter One (2)

Section 2 'How can we recognize an acid?'

a Safety spectacles
b Test-tubes
c Test-tube rack
d *Worksheet A*, if desired
e 1M hydrochloric acid, labelled 'Acid – Section 2'
f 1M sodium hydroxide solution, labelled 'Solution X – Sections 2 and 3'

The following chemical indicators, all in dropping-bottles:

g Methyl orange
h Phenolphthalein
i Cresol red
j Thymol blue
k Bromophenol blue
l Methyl red
m Bromothymol blue

Note – Any chemical indicators will do. These are simply suggestions from the indicators available in the author's Chemistry Department stock cupboard!

The following vegetable dyes in solution, all in dropping-bottles:

n Red cabbage extract (prepared by boiling 500 g of red cabbage in 1 dm^3 of water for 20 minutes; make the final volume up to 1 dm^3)
o Beetroot extract (75 g of finely chopped beetroot boiled in 100 cm^3 of water for 20 minutes; make the final volume up to 100 cm^3)
p Tea extract (leave 1 tea-bag to stand for 30 minutes in 100 cm^3 of boiling water)
q Litmus solution

Changes in acidity, Chapter One (3)

Section 3 'The Universal Indicator and pH'

a Safety spectacles
b Test-tubes
c Test-tube rack
d Dropping (teat) pipette
e Measuring cylinder, 10 cm^3
f *Worksheet B*, if desired

g 0.1M acetic acid
h 0.1M ammonia
i Universal Indicator solution, in dropping-bottles
j Item *f* of apparatus list (2)

Changes in acidity, Chapter One (4)

Section 4 'Getting rid of stomach ache'

a Safety spectacles
b Test-tubes
c Test-tube rack
d Dropping-pipette
e Spatula

f 0.01M hydrochloric acid
g Universal Indicator solution
h BiSoDol – 'recommended dose' for the experiment is 1 spatula measure
i Milk of Magnesia – use a 10 % aqueous solution or a suspension: 'recommended dose' is 1 cm^3
j Alka-seltzer – 1 tablet per 25 cm^3 water 'recommended dose' is 1 cm^3
k Other indigestion remedies as necessary

ANSWERS TO QUESTIONS IN CHAPTER ONE

1 Acids have a special taste

a Acids have a sour or sharp taste.
b Oranges, lemons, grapefruit, vinegar, sherbet, rhubarb, etc.

These questions appear on *Pupils' book* page 1.

2 How can we recognize an acid?

a Results should be as shown in the tables below.

Indicator used	Colour in acid solution	Colour in water	Colour in alkali solution
Red cabbage extract	red	red	green
Beetroot dye	purple	purple	yellow
Cold tea	yellow	brown	brown
Litmus (an extract from lichen)	red	purple	blue

Name of chemist's indicator	Colour of indicator	Colour in acid solution	Colour in water	Colour in solution X
Methyl orange	orange	red	yellow	yellow
Phenol-phthalein	colourless	colourless	colourless	magenta
Cresol red	red	orange	red	magenta
Thymol blue	red	magenta	yellow–green	blue
Bromophenol blue	purple	yellow	violet	violet
Methyl red	red	red	yellow	yellow
Bromothymol blue	blue	yellow	blue	blue

3 The Universal Indicator and pH

d Universal Indicator is red in acid solution.
e Universal Indicator is purple (*1*) in ammonia solution and (*2*) in solution X.
f Universal Indicator is more useful than other simple indicators because it tells us how acidic or alkaline a solution is. The simple indicators only tell us whether it is acidic or alkaline.
g An alkaline solution is one which removes acidity. It will turn Universal Indicator purple.

These questions appear on *Pupils' book* pages 2 and 3.

TWO
REACTIONS OF ACIDS

Pupils' book pages 4 to 6

SCISP *4*, 3.2.

This chapter introduces the characteristic reactions of acids as they are seen in aqueous solution.

Worksheet C can be used for recording results.

It is advisable for the teacher to introduce this work by demonstrating the techniques that will be used. The demonstration ought to include

1 Testing for hydrogen by applying a lighted splint.
2 The most suitable amount of metal oxide to add to ensure that all of it can dissolve.
3 The technique for heating a test-tube safely. When acids are heated with metal oxides, it would be safer to use boiling-tubes.



4 Reacting the acid with metal hydroxide solution in the presence of Universal Indicator.

5 Testing for carbon dioxide. Bubble the gas through lime water either after collecting the gas in a teat pipette or by fitting a delivery tube to the test-tube. In the past, pupils have found using a delivery tube much easier and they get more reliable results.

1 Reactions with metals

The reactions with magnesium are the fastest and hydrogen is easily detected with all the acids used. With zinc and iron, effervescence will be seen in all cases, but in some of them, not enough hydrogen is produced for the test to work.

2 Reactions with metal oxides

If these reactions are to work properly, it is important to use only a 'small' spatula measure of metal oxide. A full spatula measure may mean there is too much oxide and it will not dissolve completely.

3 Reactions with metal hydroxides

Since calcium hydroxide is only slightly soluble in water, lime water will not be as concentrated as the solutions of sodium hydroxide and potassium hydroxide used. As a result, pupils will need to add more of the calcium hydroxide solution (lime water) in order to see the same effect.

4 Reactions with metal carbonates

Pupils should have no difficulty detecting carbon dioxide by bubbling the gas through lime water.

Salt preparation – Each of the reactions studied can be used to prepare salts. At this point, teachers may wish to extend this work to include preparing crystals of salts. They can find further information about this by referring to Revised Nuffield Chemistry *Teachers' guide II*, Section A20.5, pages 264–265.

5 Word equations

The various reactions seen in the experiments are now described by means of word equations. One example of each type of reaction is given in the *Pupils' book*, together with the names of the salts obtained from each acid.

APPARATUS

Changes in acidity, Chapter Two (5)

Section 1 'Reactions with metals'

a Safety spectacles
b Test-tubes
c Test-tube rack
d Wooden splints
e Bunsen burner
f Spatula
g *Worksheet C*
h 1M hydrochloric acid
i 0.5M sulphuric acid
j 1M nitric acid
k 1M formic acid
l 1M acetic acid
m 1M citric acid
n Granulated zinc
o Magnesium ribbon
p Iron filings

Changes in acidity, Chapter Two (6)

Section 2 'Reactions with metal oxides'

a Safety spectacles
b Boiling-tubes
c Test-tube rack
d Test-tube holder
e Spatula
f Bunsen burner
g *Worksheet C*
h–m Acids numbered *h* to *m* in list (5)
n Zinc oxide
o Copper(II) oxide
p Magnesium oxide

Changes in acidity, Chapter Two (7)

Section 3 'Reactions with metal hydroxides'

a Safety spectacles
b Test-tubes
c Test-tube rack
d Dropping-pipettes
e *Worksheet C*
f–k Acids numbered *h* to *m* in list (5)
l Universal Indicator solution
m 1M sodium hydroxide solution
n 1M potassium hydroxide solution
o 0.02M calcium hydroxide solution, *i.e.* lime water

Changes in acidity, Chapter Two (8)

Section 4 'Reactions with metal carbonates'

a Safety spectacles
b Test-tubes
c Test-tube rack
d Test-tube holder
e Spatula
f Right-angled delivery tube with bung to fit test-tube or a teat pipette
g–l Acids numbered *h* to *m* in list (5)
m Anhydrous sodium carbonate
n Calcium carbonate (powder)
o Copper(II) carbonate
p Lime water

THREE
THE IMPORTANCE OF THE SOLVENT

NSS 7.24;
SCISP *4*, 3.4.

Pupils' book pages 6 and 7

1 Does the solvent matter?

The pupils investigate the behaviour of citric acid when dissolved in propanone (acetone) and water. They find that it does not show any of the normal reactions of acids when dissolved in propanone. They should be warned that propanone is flammable and should not be used near any naked flames. Particularly warn them against using a lighted splint in a forlorn test for hydrogen! *Worksheet D* can be used to record their results.



Once the pupils have completed their practical investigation, teachers may like to reinforce the ideas by a demonstration.

(*1*) This could be a similar series of experiments to those done by pupils, using hydrogen chloride dissolved in water and hydrogen chloride dissolved in methylbenzene (toluene). Instructions for preparing these two solutions are given in apparatus list (10). Once the solutions have been prepared, they can be tested by adding Universal Indicator, marble chips, and magnesium ribbon, and they can also be tested for conductivity.

(*2*) In their experiments the pupils will have discovered that citric acid dissolved in water conducts electricity and that hydrogen is produced at the cathode. (The same happens with hydrogen chloride in water.) Also, the pupils should by now be realizing that acids '*show*' their typical properties in water. The teacher can now demonstrate that aqueous solutions of acids conduct, and therefore contain ions which are not present in either pure water or pure acid. A simple conductivity testing circuit (2 carbon electrodes in a holder, a demonstration meter, and a power pack) can be used to show that pure (glacial) acetic acid and pure (distilled or de-ionized) water do not conduct electricity. If glacial acetic acid is then slowly run into water (stirred magnetically), the conductivity testing circuit immediately registers a current.

The fact that hydrogen is produced at the negative electrode means that positive hydrogen ions must now be present. These come from the acid as it dissolves in water. The ions can be represented as $H^+(aq)$. More able pupils could be made aware of the fact that these ions combine with water and are more correctly represented as $H_3O^+(aq)$.

That is, $H^+(aq) + H_2O(l) \rightarrow H_3O^+(aq)$

The H_3O^+ ion is known as the oxonium ion.

APPARATUS

Changes in acidity, Chapter Three (9)

Section 1 'Does the solvent matter?'

Pupils' experiment
a Safety spectacles
b Test-tubes
c Electrolysis cell
d Wooden splints
e Glass rod

(*Continued*)

Apparatus list (9) continued

f *Worksheet D*, if desired
g Citric acid crystals
h Distilled water
i *DRY* propanone – dry by storing over anhydrous calcium chloride for several days
j Universal Indicator paper – this must be kept dry; store in a bottle with silica gel
k Magnesium ribbon
l Powdered calcium carbonate

Changes in acidity, Chapter Three (10)

Section 1 'Does the solvent matter?'

Teacher demonstration (1)
a Safety spectacles
b Test-tubes
c Electrolysis cell or simple conductivity testing apparatus
d Solution of hydrogen chloride in water (see below)
e Solution of hydrogen chloride in methylbenzene (see below)
f Universal Indicator paper – this must be kept dry
g Magnesium ribbon (cleaned)
h Marble chips or powdered calcium carbonate

Note: Prepare the hydrogen chloride for solutions *d* and *e* by adding concentrated sulphuric acid to sodium chloride. When dissolving the gas in water or methylbenzene, it is necessary to fit the end of the delivery tube which is in the solvent with a Bunsen valve, to prevent the solvent from 'sucking back'. Dry the methylbenzene beforehand by storing it over anhydrous calcium chloride for several days.

Changes in acidity, Chapter Three (11)

Section 1 'Does the solvent matter?'

Teacher demonstration (2)
a Safety spectacles
b Beakers, 100 cm^3
c Magnetic stirrer
d Burette
e Power pack
f Demonstration meter – 100 mA, d.c. scale
g Carbon electrodes in holder
h Distilled (or, if available, de-ionized) water
i Glacial acetic acid

ANSWERS TO QUESTIONS IN CHAPTER THREE

1 Does the solvent matter?

a The citric acid crystals have no effect upon the dry indicator paper.

c The pupils' summary should read as follows.

We saw in Chapter Two that solutions of acids in water react with metals to produce **hydrogen**, and with metal carbonates to produce **carbon dioxide**. We now know that acids dissolved in water conduct electricity and that hydrogen is produced at the **cathode**. These reactions cannot happen when acids are dissolved in solvents such as **propanone**.

These questions appear on *Pupils' book* pages 6 and 7.

Electrolysis shows that lots of **ions** are present in aqueous solutions which are not present in the pure dry acid or pure water. When acids dissolve in water, large amounts of **hydrogen ions**, $H^+(aq)$, are formed. In fact they combine with water molecules to form $H_3O^+(aq)$ ions.

$H^+(aq) + H_2O(l) \rightarrow H_3O^+(aq)$

So in order to see the characteristic reactions of acids, the acid should be dissolved in **water**. The solvent does matter!

This question appears on *Pupils' book* page 7.

FOUR
NEUTRALIZATION

Pupils' book pages 8 to 10

SCISP *4*, 3.5, 3.10.

1 'Neither acidic nor alkaline'

At this point in the Unit, a solution of pH7 is referred to for the first time as a neutral solution. The reaction taking place when an alkali removes acidity is said to be neutralization. Pupils are told that neutralization reactions involve converting H^+ (or H_3O^+) ions into water molecules, and that for this to happen, hydroxide ions, OH^-, are needed. Alkaline solutions contain lots of these.

If teachers feel that more able pupils should be given the opportunity to deduce this from their practical work they could direct such pupils straight to section 2.

2 Neutralization reactions

Pupils carry out neutralization reactions following temperature changes and pH changes. *Worksheet E* can be used for recording results. It also has grids to help pupils to plot these results. For more able pupils, two other Worksheets are available which will help them to interpret their results quantitatively.

Worksheet F More neutralization reactions
This helps the pupils to calculate the molar heat of neutralization of hydrochloric acid. The Worksheet reminds pupils that they met the mole in *Particles at work* and suggests that if they need to revise they can read Chapter Seven and do *Worksheets D, E, F,* and *G* of that Unit. Pupils may also need to have terms such as 'molar solution', 'one molar', explained now (they will meet these again in Chapter Seven).

A temperature rise of about 6.5 °C was obtained in a trial experiment when 10 cm^3 of 1M hydrochloric acid were mixed with 10 cm^3 of 1M sodium hydroxide solution.

If 4.2 J raise the temperature of 1 cm^3 of water by 1 °C then (4.2 × 20 × 6.5) J raise the temperature of 20 cm^3 by 6.5 °C *i.e.* 546 J are needed (produced).

0.01 mole of hydrochloric acid is used, *i.e.*, $\frac{10}{1000} \times 1$ mole

∴ The heat produced when 1 mole of hydrochloric acid is neutralized would be (546 × 100) **J = 54.6 kJ mol^{-1}**

If further pairs of acids and alkalis are investigated it is not necessary to use the titration procedure. Simply measure the temperature rise obtained when equal volumes of the liquids are mixed.

Pupils should find that the heat of neutralization is about the same for all the acids and alkalis used. This is because in neutralization reactions the main chemical change occurring is

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

(Strictly speaking, this is an equilibrium, but at this level pupils may regard it as a simple irreversible reaction.)

Any other ions present in the solutions before mixing are unchanged at the end. We refer to such ions as spectator ions.

Worksheet G The mole
In their practical work, the pupils will have found that 10 cm^3 of 1M hydrochloric acid have reacted with 10 cm^3 of 1M sodium hydroxide solution.

Since a 1M solution contains 1 mole of solute in 1000 cm^3 of solution, then 10 cm^3 of the solution contain $\frac{10}{1000} \times 1$ mole = 0.01 mole.
The same number of moles of sodium hydroxide is used.
To show that the number of moles reacting together is the same, the equation for the reaction is written as

$HCl(aq) + NaOH(aq) \rightarrow$ products ($NaCl(aq) + H_2O(l)$)

The Worksheet then goes on to develop mole calculations using acid/alkali reactions to obtain further useful information on, for example, unknown molarities and volumes needed for neutralization.

Worksheet A **Changes in acidity**

Chapter One What is an acid?

2 **How can we recognize an acid?** (*Pupils' book* pages 1 and 2)

Record your results for the different vegetable dyes in this table.

Vegetable dye used	**Colour of vegetable dye**	**Colour in acid solution**	**Colour in water**	**Colour in solution X**
Red cabbage juice				
Beetroot juice				
Tea extract				
Litmus (an extract from *lichen* – a moss)				

The table below can be used to record the results of your experiment using indicators made by chemists. Insert the name of the indicator in the first column (copy it carefully from the bottle).

Name of chemist's indicator	**Colour of indicator**	**Colour in acid solution**	**Colour in water**	**Colour in solution X**

Worksheet B Changes in acidity

Chapter One What is an acid?

3 The Universal Indicator and pH (*Pupils' book* pages 2 and 3)

The volume of acetic acid solution used = 5 cm^3.

Record your results in this table.

Volume of ammonia solution added, in cm^3	**Colour of solution**
none	
0.5	
1.0	
1.5	
2.0	
2.5	
3.0	
3.5	
4.0	
4.5	
5.0	

Volume of ammonia solution added, in cm^3	**Colour of solution**
5.5	
6.0	
6.5	
7.0	
7.5	
8.0	
8.5	
9.0	
9.5	
10.0	

Worksheet C **Changes in acidity**

Chapter Two Reactions of acids (*Pupils' book* pages 4 to 6)

Characteristic reactions

Reaction investigated	**Hydrochloric acid**	**Nitric acid**	**Sulphuric acid**
With METAL Name(s) of metal(s) used:			
With METAL OXIDE Name(s) of metal oxides(s) used:			
With METAL HYDROXIDE Name(s) of metal hydroxide(s) used:			
With METAL CARBONATE Name(s) of metal carbonate(s) used:			

(Continued)

Worksheet C, Changes in acidity, *continued*

Reaction investigated	**Formic acid**	**Acetic acid**	**Citric acid**
With METAL Name(s) of metal(s) used:			
With METAL OXIDE Name(s) of metal oxide(s) used:			
With METAL HYDROXIDE Name(s) of metal hydroxide(s) used:			
With METAL CARBONATE Name(s) of metal carbonate(s) used:			

Worksheet D **Changes in acidity**

Chapter Three The importance of the solvent

1 **Does the solvent matter?** (*Pupils' book* pages 6 and 7)

Record your results in this table.

Test	Citric acid in water	Citric acid in propanone
pH of solution		
Reaction with calcium carbonate		
Reaction with magnesium ribbon		
Effect of electricity		

2 **Neutralization reactions** (*Pupils' book* pages 8 and 9)

The volume of hydrochloric acid used in each experiment = 10 cm^3.

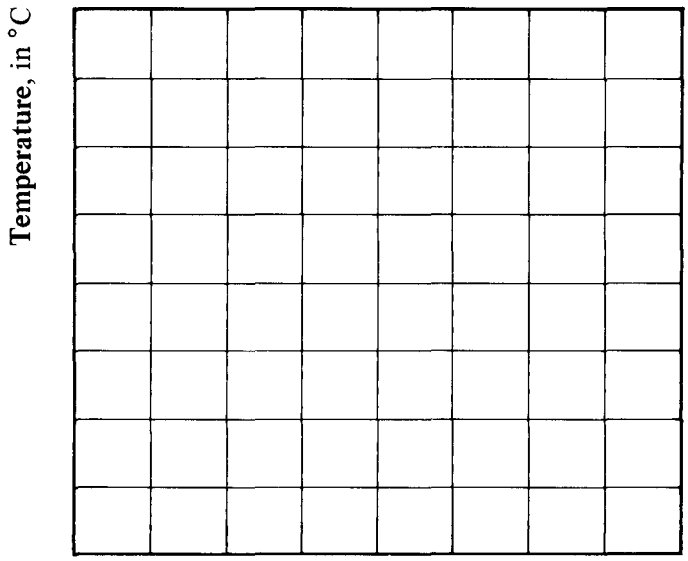
Your results for the two parts of this investigation can be recorded in this table.

Volume of sodium hydroxide solution added, in cm^3	**Experiment 1 Temperature**, in °C	**Experiment 2 pH**
none		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

You can now plot these results on the grids on the next page.

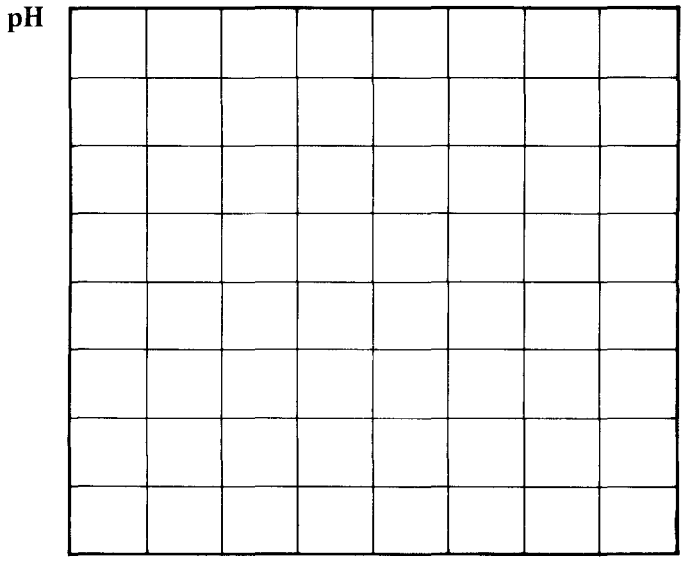
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1 *Following temperature changes*



Volume of alkali added, in cm^3

2 *Following* pH *changes*



Volume of alkali added, in cm^3

Chapter Four, section 2 (*Pupils' book* pages 8 and 9)

More neutralization reactions

The first method of following neutralization reactions which you tried was called 'Following temperature changes'. This showed you how much alkali was needed to react with all of the acid which you used. We are now going to work out how much heat was produced. It is known that

4.2 joules are required to raise the temperature of 1 g of water by 1 °C.

a Copy out this last statement.
b What was the total volume of solution when all of the acid had been neutralized?
c What was the rise in temperature?
d Calculate the amount of heat given out. Set out your calculation like this.

If 4.2 J are required to raise the temperature of 1 cm^3 of water by 1 °C
(4.2 × V) J are required to raise the temperature of V cm^3 of water by 1 °C
(4.2 × V × T) J are required to raise the temperature of V cm^3 of water by T °C
(Divide by 1000 to get your answer in kilojoules, kJ.)

In the next stage of our calculation we use the mole again. We first used the mole in *Particles at work*. If you cannot remember what chemists mean when they talk about moles, re-read Chapter Seven of that Unit and do *Worksheets D*, *E*, *F*, and *G* which go with it.

The hydrochloric acid which you used in the experiment 'Following temperature changes' was 1 molar. This means that 1 mole of hydrogen chloride (hydrochloric acid gas) had been dissolved to make 1000 cm^3 of solution. We only used 10 cm^3 of this solution.

e Now calculate how much heat would have been produced if we had neutralized 1000 cm^3 of the 1M hydrochloric acid.
f Copy the information below, filling in the gap at the end with your result.

THE AMOUNT OF HEAT PRODUCED WHEN 1 MOLE OF HYDROCHLORIC ACID IS NEUTRALIZED IS KNOWN AS THE MOLAR HEAT OF NEUTRALIZATION OF HYDROCHLORIC ACID.
MOLAR HEAT OF NEUTRALIZATION = ... kJ mol^{-1}

(Your teacher may let you continue the experiment to investigate other pairs of acids and alkalis.)

Chapter Four, section 2 (*Pupils' book* pages 8 and 9)

The mole

You should know that a mole of any substance always contains the same number of particles (*i.e.* 6×10^{23}).

1000 cm³ of a molar solution contains 6×10^{23} solute particles, *i.e.* a mole of particles.

1000 cm³ of a 2 molar solution contains 2 moles of particles.

500 cm³ of a 1 molar solution contains 0.5 mole of particles.

25 cm³ of a 1 molar solution contains $\frac{25}{1000}$ mole of particles.

25 cm³ of a 2 molar solution contain $\left(\frac{25}{1000} \times 2\right)$ mole of particles.

There is a simple formula to help us to work out the number of moles.

$$\text{NUMBER OF MOLES} = \frac{\text{VOLUME}}{1000} \times \text{MOLARITY}$$

In your experiments you will have found that equal volumes of 1M (one molar) hydrochloric acid and 1M solution were needed for neutralization. Therefore, equal numbers of moles were reacting.

Number of moles in each case $= \left(\frac{10}{1000} \times 1\right) = 0.1$ mole

This means that the equation for this reaction is

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Now that we know this equation we can make very good use of it.

Suppose we found that 10 cm³ of 2M sodium hydroxide solution neutralize 20 cm³ of hydrochloric acid.

The number of moles of sodium hydroxide reacting $= \left(\frac{10}{1000} \times 2\right)$ mole

$= 0.02$ mole

The equation tells us that this is also the number of moles of hydrochloric acid.

If 20 cm³ of hydrochloric acid contain 0.02 mole then

1000 cm³ of hydrochloric acid contain $\left(0.02 \times \frac{1000}{20}\right) = 1$ mole

In other words the hydrochloric acid is one molar.

Now try these problems for yourself.

a 50 cm³ of hydrochloric acid were required to neutralize 25 cm³ of 2M sodium hydroxide solution. What is the molarity of the acid?

b How much 4M hydrochloric acid will be needed to neutralize 100 cm³ of 0.5M sodium hydroxide solution?

c 25 cm³ of 2M sulphuric acid were needed to neutralize 100 cm³ of 1M sodium hydroxide solution. Use this information to work out the equation for the reaction.

d Now that you know the equation, suppose that 50 cm³ of 0.5M sulphuric acid reacted with 10 cm³ of sodium hydroxide solution. What is the molarity of the alkali?

e How much 0.1M sulphuric acid is needed to neutralize 10 cm³ of 0.5M potassium hydroxide solution?

f It was found that equal numbers of moles of sulphuric acid and calcium hydroxide reacted together in a neutralization reaction. What is the formula of calcium hydroxide and what is the equation for the reaction?

Worksheet H **Changes in acidity**

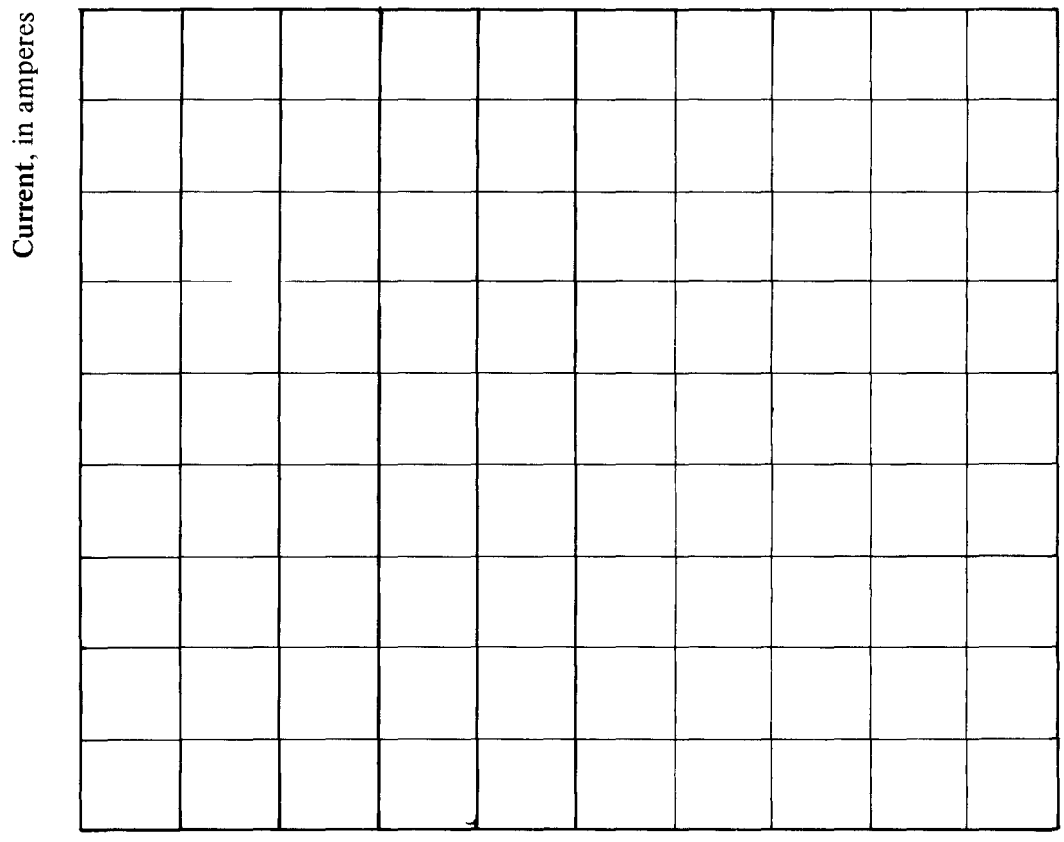
Chapter Five Barium hydroxide(aq) + sulphuric acid(aq) (*Pupils' book* pages 10 to 12)

1 What happens when these two solutions are mixed?

Record your results in this table.

Volume of sulphuric acid added, in cm^3	**Current**, in amperes
0	
5	
10	
15	
18	
20	
22	
23	
24	
25	
26	
30	

Now plot your results on this grid.



Worksheet 1 Changes in acidity

Chapter Six Acid pollution in the air

1 The effect of sulphur dioxide

(*Pupils' book* pages 12 to 15)

NAME OF METAL	APPEARANCE OF THE METAL			
Lesson 1 Date				
Lesson 2 Date				
Lesson 3 Date				
Lesson 4 Date				
Lesson 5 Date				

Worksheet J **Changes in acidity**

Chapter Seven Factors affecting rate of corrosion

1 Changes in surface area (*Pupils' book* page 16)

Record your results in this table.

Time, in seconds	**MASS OF APPARATUS**, in grams		
	large chips	medium chips	small chips
0			
15			
30			
45			
60			
75			
90			
105			
120			
135			
150			
165			
180			
195			
210			
225			
240			
255			
270			
285			
300			

APPARATUS

Changes in acidity, Chapter Four (12)

Section 2 'Neutralization reactions'

1 Following temperature changes
a Safety spectacles
b Insulated glass calorimeter or plastic beaker, and rod
c Thermometer, 0–50 °C
d Measuring cylinder, 25 cm^3
e Burette in clamp stand
f 1M hydrochloric acid
g 1M sodium hydroxide solution
h *Worksheet E*, if desired
For further work suggested in *Worksheet F*, the following will also be needed:
i 1M nitric acid
j 0.5M sulphuric acid
k 1M potassium hydroxide solution
l *Worksheet F*

Changes in acidity, Chapter Four (13)

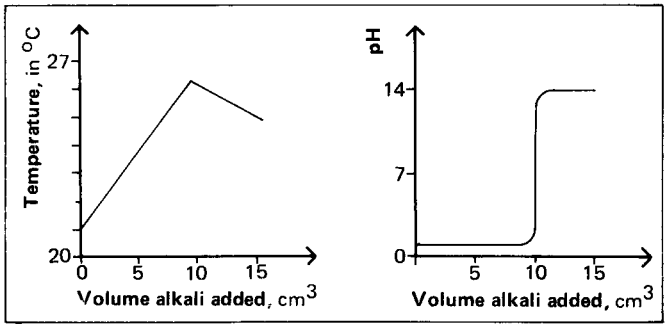
Section 2 'Neutralization reactions'

2 Following pH changes
a Safety spectacles
b Beaker, 100 cm^3
c Burette in clamp stand
d White tile
e Measuring cylinder, 25 cm^3
f pH meter, if available
g 1M hydrochloric acid
h 1M sodium hydroxide solution
i Universal Indicator solution

ANSWERS TO QUESTIONS IN CHAPTER FOUR

2 Neutralization reactions

a–b The general shape of the graphs pupils might expect to obtain are as follows.



c The amount of alkali needed for neutralization should be about 10 cm^3 in each case, that is, at the peak of the graph of temperature *versus* volume of alkali or where the sudden increase in pH occurs in the graph of pH *versus* volume of alkali.

Worksheet F
a to *e* These are the pupils' experimental results and their calculations.
f Answers in the range 40 to 60 kJ mol^{-1} can be expected.

These questions appear on *Pupils' book* pages 8 and 9 and on *Worksheet F.*

Worksheet G
a 25 cm^3 of 2M sodium hydroxide contain $\frac{25}{1000} \times 2$ mole
$= 0.05$ mole.
Since $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$
0.05 mole of hydrochloric acid is present in 50 cm^3
$\therefore 0.05 \times \frac{1000}{50}$ mole is present in 1000 cm^3
$\therefore$ the solution is 1 molar.
b 100 cm^3 of 0.5M sodium hydroxide contain
$\frac{100}{1000} \times 0.5$ mole
$= 0.05$ mole
$\therefore$ 0.05 mole of hydrochloric acid is needed for neutralization.
1000 cm^3 of hydrochloric acid contain 4 moles
$\therefore 1000 \times \frac{0.05}{4}$ cm^3 contain 0.05 mole
$\therefore$ volume of 4M hydrochloric acid required $= 12.5$ cm^3.
c 25 cm^3 of 2M sulphuric acid contain $\frac{25}{1000} \times 2$ mole
$= 0.05$ mole.
100 cm^3 of 1M sodium hydroxide contain
$\frac{100}{1000} \times 1$ mole
$= 0.1$ mole.
$\therefore$ the ratio of moles of sulphuric acid to moles of sodium hydroxide is 1:2.
$\therefore$ the equation for the reaction is
$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$
d 50 cm^3 of 0.5M sulphuric acid contain $\frac{50}{1000} \times 0.5$ mole
$= 0.025$ mole.
The equation tells us that 0.05 mole of sodium hydroxide is needed.
$\therefore$ if 10 cm^3 of the sodium hydroxide solution contain 0.5 mole, then
1000 cm^3 will contain $0.05 \times \frac{1000}{10} = 5$ moles
That is, the sodium hydroxide solution is 5 molar.
e 10 cm^3 of 0.5M potassium hydroxide contain
$\frac{10}{1000} \times 0.5$ mole $= 0.005$ mole
$\therefore$, since
$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$
0.0025 mole of sulphuric acid is required.
If 1000 cm^3 of sulphuric acid contain 0.1 mole, then
$1000 \times \frac{0.0025}{0.1}$ cm^3 contain 0.0025 mole.
$\therefore$ volume of sulphuric acid needed $= 25$ cm^3
f The equation can be written as
$H_2SO_4(aq) + Ca(OH)_x(aq) \rightarrow$ products.
Since neutralization requires each H^+ ion in the acid to react with an OH^- ion from the alkali, then x must equal 2.
That is, the equation for the reaction is
$H_2SO_4(aq) + Ca(OH)_2(aq) \rightarrow CaSO_4(aq) + 2H_2O(l)$

These questions appear on *Worksheet G.*

FIVE

BARIUM HYDROXIDE(aq) + SULPHURIC ACID(aq)

Pupils' book pages 10 to 12

SCISP *4*, 3.7.

This reaction is used to summarize the ideas introduced in the first four chapters. It is suggested that the teacher should show the pupils what happens when the solutions are mixed – a simple test-tube reaction. There could then be a discussion based upon questions *a* to *e* in the *Pupils' book*. From this, pupils should realize that when these two solutions are mixed, ions are continuously being removed from the solution and thus the solution's conductivity decreases. The conductimetric titration demonstrates this; neutralization occurs when the current (a.c.) drops to zero. There is a photograph of the apparatus, set up, on page 11 of the *Pupils' book*; see also list (14) in this *Guide*.

Instructions for demonstration

1 Put 50 cm^3 of 0.1M barium hydroxide solution into the 100 cm^3 beaker and put this on the magnetic stirrer. Add 5 drops of phenolphthalein indicator.

2 Put the carbon electrodes in the solution. They should be connected with the demometer and power pack. Alternating current is used in order to prevent electrolysis.

3 Fill the burette with the sulphuric acid.

4 Switch on the stirrer and add the sulphuric acid. Record the current at the intervals suggested on *Worksheet H.*

For further information, see Revised Nuffield Chemistry, *Teachers' guide II*, section A20.4, pages 261–2.

During the titration, pupils can record their results on *Worksheet H.*

APPARATUS

Changes in acidity, Chapter Five (14)

Section 1
'What happens when these two solutions are mixed?'

Teacher demonstration (1) (see diagram)
a Safety spectacles
b Test-tubes
c Test-tube rack
d Dropping-pipette
e Measuring cylinder, 10 cm^3

Teacher demonstration (2): conductimetric titration
f Safety spectacles
g Beaker, 100 cm^3
h Burette in clamp stand
i Pipette, 25 cm^3 (or measuring cylinder, 100 cm^3)
j Safety pipette filler
k Magnetic stirrer
l Demonstration meter – 1 A, a.c. scale
m *Worksheet H*, if desired

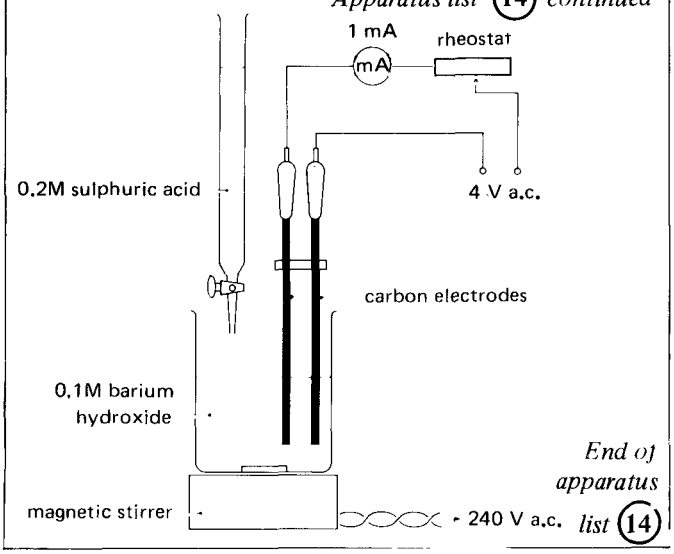
(Continued)

Apparatus list (14) *continued*

n Power pack for a.c. supply
o Carbon electrodes in holder
p 0.1M barium hydroxide solution (*WARNING* – barium ions in solution are extremely *POISONOUS*)
q 0.2M sulphuric acid
r Phenolphthalein indicator

(Continued)

Apparatus list (14) *continued*



End of apparatus list (14)

ANSWERS TO QUESTIONS IN CHAPTER FIVE

a When the two solutions are mixed, a white precipitate is produced in a colourless liquid.

b Barium sulphate and water.

c barium hydroxide + sulphuric acid → **barium sulphate** + **water**

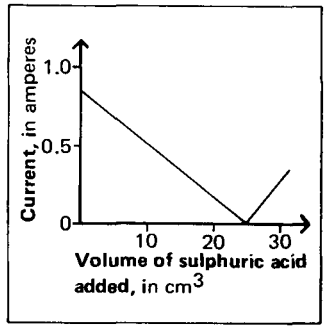
d **barium** ion (positive) + **sulphate** ion (negative) → **barium sulphate (salt)**

e **hydrogen** ion (positive) + **hydroxide** ion (negative) → **water**

f The barium ions and sulphate ions come together to form an insoluble crystalline solid. The ions are in fixed positions in the lattice and are unable to move.

g The hydrogen and hydroxide ions combine to form unionized water molecules.

i The graph should look like this.



These questions appear on *Pupils' book* pages 10 to 12.

j Alternating current was used so that electrolysis would not take place.
k The current decreases as sulphuric acid is added because the reaction is removing ions from the solution.
l The phenolphthalein, which is pink in the barium hydroxide solution, loses colour as soon as the neutralization reaction is complete. The indicator is colourless in acidic solutions.

These questions appear on *Pupils' book* page 12.

m At the moment when the neutralization reaction is complete there are no ions which are free to move and so no current flows.
n The current increases after this point because sulphuric acid is now in excess and the ions present in it allow a current to flow.

These questions appear on *Pupils' book* page 12.

SIX
ACID POLLUTION IN THE AIR

Pupils' book pages 12 to 15

NSS 7.24;
SCISP *4*, 3.1.

1 The effect of sulphur dioxide

Sulphur dioxide is the main acidic pollutant in the air. The teacher should demonstrate some reactions of this gas before the principal work of the chapter begins. A sulphur dioxide cylinder is particularly useful here. Its reactions with

1 Universal Indicator solution (green → red)
2 acidified solution of potassium manganate(VII) (purple → colourless)
3 acidified solution of potassium dichromate (orange → green)

are particularly interesting. The decolorization of a very dilute solution of potassium manganate(VII) (pale pink) is used as a very sensitive test for sulphur dioxide in the next demonstration.

The next demonstration shows that sulphur dioxide is a combustion product when coal is burned. Coal is heated and the gaseous products are drawn through glass wool to remove any solid, before they are bubbled through the dilute solution of potassium manganate(VII). Air and the combustion products are drawn through the apparatus continually, by means of a water pump. A photograph of the apparatus to be used can be seen in the *Pupils' book* (page 13), and a diagram appears in apparatus list (15) of this *Guide*.

In order to demonstrate the increase in corrosion caused by sulphur dioxide in the atmosphere, a number of different metals can be left exposed to different environments, such as dry air, moist air, and moist air containing sulphur dioxide.

This experiment is set up, with the metal samples in sandwich boxes. Pupils observe the boxes over a period of days, to compare rates of corrosion. In a trial experiment using the metals in apparatus list (17), some corrosion was obvious overnight in the box containing sulphur dioxide; it was particularly bad after four days.

Worksheet I is available for pupils to record their results.

Pupils who have studied the Unit *Is the environment changing?* will have read a newspaper article about 'acid rain' pollution.

APPARATUS

Changes in acidity, Chapter Six (15)

Section 1 'The effect of sulphur dioxide'

Demonstration of the properties of sulphur dioxide
a Safety spectacles
b Test-tubes
c Test-tube rack
d Sulphur dioxide cylinder
e Universal Indicator solution
f Acidified potassium manganate(VII) solution
g Acidified potassium dichromate solution

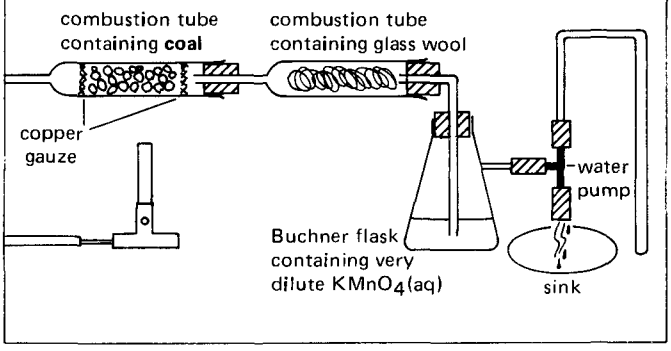
If a sulphur dioxide cylinder is not available, SO_2 can be prepared by adding hydrochloric acid (2M) to sodium sulphite. Alternatively, a solution of sodium sulphite or disulphate (IV) can be used as 'sulphur dioxide solution'.

Changes in acidity, Chapter Six (16)

Section 1 'The effect of sulphur dioxide'

Demonstration to show that SO_2 *is produced when coal burns*

a Safety spectacles
b 2 combustion tubes
c 2 single-hole bungs to fit combustion tubes
d Delivery tube connecting second combustion tube to *e*
e Buchner flask
f Water suction pump
g Bunsen burner
h Stand and clamp
i Glass wool or Rocksil
j Coal
k Copper gauze
l Acidified potassium manganate(VII) solution (very dilute – pale pink)



Changes in acidity, Chapter Six (17)

Section 1 'The effect of sulphur dioxide'

Pupils' experiment to show the corrosive effect of SO_2

a 3 transparent plastic sandwich boxes with lids
b Polystyrene tiles to line bottom of each box in order to support the metals
c *Worksheet I*, if desired
d For box 1, a container holding cottonwool soaked in 20 % sodium metabisulphite solution
e For box 2, a container holding cottonwool soaked with water
f For box 3, a container holding silica gel
3 strips of each of the following metals:
g Aluminium
h Copper
i Magnesium
j Nickel
k Silver steel
l Mild steel
m Tin
n Zinc

ANSWER TO QUESTION IN CHAPTER SIX

d Acid pollution in the air causes limestone or marble to corrode because both are calcium carbonate and this reacts with acids, producing soluble calcium chloride, water, and carbon dioxide. The carbonate dissolves.

This question appears on *Pupils' book* page 14.

SEVEN

FACTORS AFFECTING RATE OF CORROSION

Pupils' book pages 16 and 17

NSS 7. 24;
SCISP *4*, 3.8.

The chapter introduces pupils to the factors which affect the rates of chemical reactions, by linking these with corrosion. The reaction mainly used is that between marble chips and dilute hydrochloric acid (and by analogy, between ornamental stonework and dissolved sulphur dioxide). Obviously catalysis is not appropriate here but some teachers may wish to introduce this as extension work.

1 Changes in surface area

The teacher does this experiment as a demonstration, with pupils recording results as the reaction proceeds (*Worksheet J* is available for the purpose); this is a well tried and tested Nuffield Chemistry experiment (see Revised Nuffield Chemistry, Topic A18.3). The advent of the electronic digital read-out balance makes it much easier for pupils to take part. Marble chips of three different sizes are used. The use of powered calcium carbonate is not advised since the reaction is very fast and not easy to control.

2 Changes in concentration

The success of this practical will depend upon the size of the spatula measure of calcium carbonate used. Teachers are advised to try this out first so they can give clear instructions on the ideal size of a 'spatula measure of powdered calcium carbonate'

3 Changes in temperature

It was found that powdered calcium carbonate was not suitable for this investigation. It dissolved too rapidly at high temperatures. So marble chips of approximately 3 × 3 × 3 mm were used. These can be made by hammering 13 mm graded chips. It is not difficult to break them up.

If pupils do this experiment, it is particularly important that they wear safety spectacles, since the acid used is 4M. It is also suggested that they warm their acid in a water bath.



APPARATUS

Changes in acidity, Chapter Seven (18)

Section 1 'Changes in surface area'

a Safety spectacles
b Top-pan balance
c Conical flasks, 100 cm^3
d Measuring cylinder, 100 cm^3
e Stopclock
f Cottonwool
g *Worksheet J*, if desired

h 2M hydrochloric acid (40 cm^3 per experiment)
i Marble chips of 3 different sizes (20 g per experiment)

Changes in acidity, Chapter Seven (19)

Section 2 'Changes in concentration'

a Safety spectacles
b Test-tubes
c Test-tube rack
d Spatula
e Stopclock

f 2M hydrochloric acid
g 1M hydrochloric acid
h 0.5M hydrochloric acid
i Powdered calcium carbonate

Changes in acidity, Chapter Seven (20)

Section 3 'Changes in temperature'

a Safety spectacles
b Test-tubes
c Test-tube rack
d Bunsen burner, tripod, gauze, and heat-proof mat
e Beaker, 250 cm^3 (water bath)
f Test-tube holders
g Stopclock
h Thermometer

i 4M hydrochloric acid
j Marble chips (about 3 × 3 × 3 mm)

ANSWERS TO QUESTIONS IN CHAPTER SEVEN

1 Changes in surface area

a The reaction is quickest in the experiment with the small marble chips.
b Surface area of large cube = 24 cm^2.
c Surface area of 8 small cubes = 48 cm^2.
d The rate of reaction increases as the particles get smaller because smaller particles have an overall greater surface area for the acid to react with.
e A carving will corrode more quickly than polished marble because it has a greater surface area.

2 Changes in concentration

b As the concentration of the acid increases, the calcium carbonate reacts more quickly.
c A carving will corrode more quickly when there is a lot of sulphur dioxide in the atmosphere because more sulphur dioxide will dissolve, making the concentration of acid in the rainfall, etc., much greater.

3 Changes in temperature

b As the temperature increases, the rate of reaction increases.
c Corrosion is more rapid in hot countries, because rate of reaction increases with temperature.

These questions appear on *Pupils' book* pages 16 and 17.

EIGHT
DESIRABLE CHANGES IN ACIDITY

Pupils' book pages 18 to 20

Finally pupils experience some useful effects of changes in acidity.

1 Pickling

The pupils' investigation has been adapted from the Nuffield Advanced Chemistry Special Study *Food science*.

The experiment involves investigating the effect of pH upon the rate at which apples go brown. The teacher will need to help pupils to prepare the apple pulp. Experience has shown that Bramley apples are very suitable for this experiment. A homogenate of about 100 g apples (peeled and cored) + 100 cm^3 water is made in a liquidizer and the resulting pulp will probably be enough for four or five groups of pupils. The pulp must be used no more than five minutes after it has been made. Instructions for preparing the buffer solutions are given in apparatus list (21).

2 pH in the garden

The *Pupils' book* does not contain any suggestions for practical work involving pH measurements of soil samples. However, schools with a rural or environmental studies department may find this sort of work easy to introduce. Pupils may even be able to do some longterm investigation into how well plants grow under different pH conditions. The problem of mixing lime and fertilizer is mentioned and pupils can themselves produce ammonia by carrying out the simple test-tube experiment suggested.

3 A sting in the tail

This introduces some simple everyday treatments for wasp and bee stings. It might be necessary to allow pupils to find out the pH of bicarbonate of soda solution.

APPARATUS

Changes in acidity, Chapter Eight (21)

Section 1 'Pickling'

a Safety spectacles
b Test-tubes
c Test-tube rack
d Spatulas
e Dropping-pipettes
f Liquidizer
g Stopclock

h Bramley apples (100 g = 1 medium-sized apple)
i Distilled water
j Buffer solutions. These should be prepared by mixing 0.04M disodium hydrogen phosphate solution and 0.2M citric acid solution in the ratios by volume indicated in the table below.

0.04M disodium hydrogen phosphate	0.4	4.1	7.7	10.3	12.6	16.5	19.4
0.2M citric acid	19.6	15.9	12.3	9.7	7.4	3.5	0.6
pH	2	3	4	5	6	7	8

Changes in acidity, Chapter Eight (22)

Section 2 'pH in the garden'

a Safety spectacles
b Test-tube and test-tube holder
c Bunsen burner

d Calcium hydroxide
e Ammonium sulphate
f Universal Indicator paper

ANSWERS TO QUESTIONS IN CHAPTER EIGHT

1 Pickling

c As pH decreases so does the rate at which browning occurs. Below a pH of 3, there are no visible signs of browning.
d In solutions of low pH, bacteria cannot grow and enzymes are destroyed. Since these are the main factors which make food deteriorate, it is preserved by storage in acid solution.

2 pH in the garden

a Lime is an alkali, and will therefore increase pH as it dissolves and mixes with the soil.
c The ammonia gas produced turns the damp Universal Indicator paper blue/purple.

3 A sting in the tail

a Since wasp stings can be treated with vinegar, there must be some substance in the sting which is alkaline. Bee stings must contain an acidic substance, since we treat them with bicarbonate of soda which is a mild alkali.

These questions appear on *Pupils' book* pages 19 and 20.

FINAL QUESTIONS

Pupils' book pages 20 and 21

ANSWERS

The first two questions could be given to pupils to solve as a practical test, but the answers below are to be expected if they are set as written test.

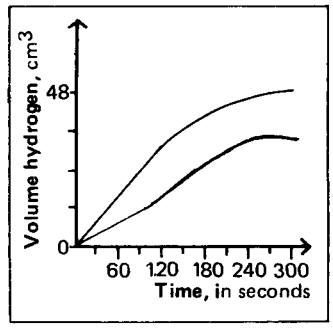
1 *1* Firstly some dye must be extracted from the beetroot. Chop the beetroot up, add water, and boil for about 10 minutes.
2 Test the acid and alkali provided, with the beetroot dye. Observe the colour in each solution.
3 Add beetroot dye to solution X, observe the colour, and compare this with the results with acid and alkali.

2 Label the three bottles *A*, *B*, and *C*.
Mix *A* with *B*, *A* with *C*, and *B* with *C*.
One pair should give off a gas (carbon dioxide) and another pair show a marked rise in temperature.
The solution common to both pairs is the dilute sulphuric acid.
The other liquid which reacts to give off carbon dioxide is the sodium carbonate solution.
The other liquid which reacts to give a marked rise in temperature is the sodium hydroxide solution.

This question and the one opposite appear on *Pupils' book* page 20.

3 *a* The gas given off is carbon dioxide.
b Malachite is a metal carbonate.
c The metal present is copper.
d The pupil ground up the lump so that the reaction would take place more quickly.

4 *a* The graph should look like this.



b The reaction with the magnesium powder was faster.
c The reaction is quicker with powder because there is a greater surface area for the acid to react with.

5 *a* Liquids *A* and *C* behave as acids.
b These are the only liquids which react in the tests listed.
c The other liquids cannot show acidic properties because water is not present.

These questions appear on *Pupils' book* pages 20 and 21.

6 *a* sulphuric acid + **copper(II) oxide** *or* **copper(II) hydroxide** → copper(II) sulphate + water

b **nitric acid** + sodium hydroxide → sodium nitrate + **water**

c **hydrochloric acid** + **iron** → iron(II) chloride + hydrogen

d nitric acid + sodium **carbonate** → **sodium nitrate** + water + **carbon dioxide**

e **formic acid** + **potassium hydroxide** → potassium formate + water

7 *a* Substance **A** is hydrogen iodide.
b Solution **B** is hydroiodic acid. It conducts electricity, producing hydrogen at the cathode and iodine at the anode. When it is shaken with t.c.e., much of the iodine transfers to the t.c.e. layer, making it purple. A solution such as **B**, containing iodide ions, reacts with silver nitrate solution, producing a pale yellow precipitate of silver iodide.

These questions appear on *Pupils' book* page 21.

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Nuffield Science 13 to 16
Beta Schofield

Editor of this Unit
Patricia Murphy

Author of this Unit
Michael Bendry

This is the *Teachers' guide* for the Unit *Changes in acidity.*

Its aim is to give teachers the fullest possible backing in the use of the *Pupils' book.* Therefore, this *Guide* contains illustrated apparatus lists and the answers to questions for each main activity in the *Pupils' book.* It also includes a central section of illustrated Worksheets, based on the activities. They contain work which will be suitable for some, but not necessarily all, pupils and are designed to be duplicated in the numbers required.

The book is introduced by an 'overall picture' showing how this Unit is linked with materials in Nuffield Secondary Science and in the Schools Council Integrated Science Project, to make up a complete 'module' on the topic. This is followed by a list of ideas which both indicates the scope of the work and helps teachers whose pupils are being prepared for an examination within a common system.

There are 44 Units in *Nuffield Science 13 to 16.* The work has been extensively tried in schools (the name given to the trials materials was CESIS). Detailed suggestions for the use of these Units are given in the *Teachers' handbook.* This describes the system of examination for which each Unit is suitable. This Unit is intended for 'D' or double certification.

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