Activity 1: Making a pH indicator

A pH indicator is a substance which has one colour when added to an acidic solution and a different colour when added to an alkaline solution. In this experiment pupils make an indicator from red cabbage. It is also possible to use other materials such as beetroot, berries or flower petals.

The experiment is in two parts. The first part involves boiling some red cabbage in water. In the second part is to test the indicator.

Apparatus and chemicals

Each working group will require:

Beaker (250 cm³)
Bunsen burner
Tripod
Gauze
Heat resistant mat
Test-tubes, 3 (see note 1)
Test-tube rack
Dropper pipette
Several pieces of red cabbage

Access to:

Dilute hydrochloric acid, 0.01 mol dm⁻³ (Low hazard at this concentration)
Sodium hydroxide solution 0.01 mol dm⁻³ (Low hazard at this concentration)
De-ionised or distilled water
Procedure

HEALTH & SAFETY: Wear eye protection throughout. Consider clamping the beaker. You should remain standing whilst water is boiling.

a) Boil about 50 cm\(^3\) of water in a beaker.
b) Add 3 or 4 small (5 cm) pieces of red cabbage to the boiling water.
c) Continue to boil the red cabbage in the water for about 5 minutes. The water should turn blue or green.
d) Turn off the Bunsen burner and allow the beaker to cool for a few minutes.
e) Place 3 test-tubes in a test-tube rack. Half-fill one of the test-tubes with acid, one with alkali, and one with distilled or de-ionised water. Label the test-tubes.
f) Use a dropper pipette to add a few drops of the cabbage solution to each test-tube. Note the colour of the cabbage solution in each of the three test-tubes.
Activity 2: ‘Neutralisation circles’

Description
Drops of dilute acid and alkali are placed a few centimetres apart on a sheet of filter paper and allowed to spread out until they meet. A few drops of Universal indicator are then placed over the moist area of the filter paper and a band of colours showing the range of colours of the Universal indicator is seen on the paper.

Procedure
Take a piece of filter paper and draw on it in pencil two circles about 1 cm in diameter and about 2 – 3 cm apart and label them ‘acid’ and ‘alkali’ respectively. Place the filter paper on a while tile and using dropping pipettes place a few drops of the appropriate solution in each circle. The solution will begin to spread out on the filter paper. Wait for a few minutes until the solutions have soaked through the filter paper towards each other and have met. Place drops of Universal Indicator solution on the area of the filter paper where the acid and alkali have met and reacted. A ‘rainbow’ is produced showing the range of colours produced by the Universal indicator.

You can dry the filter papers and stick them into your notebooks.

The reaction is

\[ \text{HCl(aq)} + \text{NaOH(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)} \]
Activity 3: An effervescent universal indicator ‘rainbow’

Description
Sodium carbonate solution is added to a burette containing a little hydrochloric acid and Universal Indicator. The two solutions react, with effervescence, and the liquid in the burette shows a ‘rainbow’ of all the colours of Universal Indicator from red through orange, yellow, green and blue to purple.

Method
Clamp the burette vertically. Add about 0.5 cm$^3$ of the universal indicator solution followed by about 10 cm$^3$ of the hydrochloric acid (irritant) to give a clearly visible red colour. Now add about 20 cm$^3$ of the sodium carbonate solution. Insert a loose plug of cotton wool in the top of the burette. The sodium carbonate and hydrochloric acid react, with effervescence, and the burette will be filled with liquid showing a ‘rainbow’ of all the colours of universal indicator from red through orange, yellow, green and blue to purple.

Health & Safety
Wear eye protection.
Activity 4: Investigation of indicators

INDICATORS are substances that, when added to solutions of different pH, change colour. You are provided with three: bromothymol blue, methyl orange and phenolphthalein

1. Begin your investigation by finding what colour each of these indicators turns when added to an acid or an alkali. To do this pour about 2 cm. depth of dilute hydrochloric acid into a test tube and add two drops of one of the indicators to find out what colour it turns with acids. Then pour about 2 cm depth of sodium hydroxide solution into another test tube and add two drops of the indicator to find out what colour it turns in alkalis. Repeat this using clean test tubes for the other two indicators. Write the colours you observe in the spaces below:

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Colour in acids</th>
<th>Colour in alkalis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromothymol blue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methyl orange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenolphthalein</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. You are now going to test two solutions with the three indicators and try to draw conclusions about them from the colours shown by the indicators. The solutions with which you are provided are boric acid solution and sodium bicarbonate solution. To investigate these, pour about 2 cm. depth of one of the solutions into each of three clean test tubes and add two drops of an indicator to one test tube. Add two drops of another indicator to the second tube and two drops of the third indicator to the third tube. From the colours shown by the indicator in each case decide whether it is indicating ACID or ALKALI. Repeat this part of the investigation for the other solution. Now record your observations and conclusions in the following table:
Results with Boric acid solution

Results with Sodium bicarbonate solution

<table>
<thead>
<tr>
<th>Colour with Bromothymol Blue</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid or alkali shown by</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromothymol Blue?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Colour with Methyl Orange</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid or alkali shown by</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methyl Orange?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Colour with Phenolphthalein</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid or alkali shown by</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenolphthalein?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Is there anything odd you notice in your results in the above table? YES/NO (Delete the answer which does not apply)

Explain your answer:

3. To demonstrate the action of these indicators further, you are going to test some solutions with a mixture of the indicators. First prepare this mixture by mixing in a test tube:

- 10 drops of Bromothymol blue,
- 5 drops of methyl orange and
- 5 drops of phenolphthalein.

Mix them well and, using a teat dropper, add two drops of this mixed indicators solution to test tubes containing 2 cm. depth of each of the following substances:

- Dilute hydrochloric acid,
- Boric acid solution,
- tap water,
- sodium bicarbonate solution and
- sodium hydroxide solution.

Record your observations in the table below:
<table>
<thead>
<tr>
<th>SUBSTANCE</th>
<th>COLOUR SHOWN BY MIXED INDICATORS SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilute hydrochloric acid</td>
<td></td>
</tr>
<tr>
<td>Boric acid solution</td>
<td></td>
</tr>
<tr>
<td>Tap water</td>
<td></td>
</tr>
<tr>
<td>Sodium bicarbonate solution</td>
<td></td>
</tr>
<tr>
<td>Sodium hydroxide solution</td>
<td></td>
</tr>
</tbody>
</table>

Have you ever seen a series of colours similar to this shown by an indicator solution? YES/NO (Delete the answer which does not apply)

Comment on the colours you see in this part of the investigation and try to explain your results:
Activity 5: Explaining acid strength

One definition of an acid is that it dissolves in water to give hydrogen ions (H\(^+\)). In fact the hydrogen ion (H\(^+\)) will associate with a water molecule to form H\(_3\)O\(^+\). One way to write the equation for an acid ‘HA’ dissolving in water is:

\[
\text{HA} + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{A}^-(aq)
\]

The A in HA does not stand for a particular element, but for the ‘acid radical’ part of the molecule. So, for example, in hydrochloric acid ‘HA’ would be HCl, and ‘A\(^-\)’ would be Cl\(^-\), whilst in ethanoic acid ‘HA’ would be CH\(_3\)COOH, and ‘A\(^-\)’ would be CH\(_3\)COO\(^-\).

Acids (and alkalis) can be described as ‘strong’ or ‘weak’, and as ‘concentrated’ or ‘dilute’.

1. What is the difference between a strong acid and a weak acid?

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

2. What is the difference between a concentrated acid and a dilute acid?

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

3. If you could see the particles (molecules, ions etc) in an acidic solution, how would you decide whether it was a solution of a strong acid or a solution of a weak acid?

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
**Classifying acid solutions**

One way to write the equation for an acid ‘HA’ dissolving in water is:

\[
HA + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)
\]

On the following pages are some diagrams of acidic solutions.

Scientific diagrams are always simplifications designed to highlight some aspects of the system represented. The diagrams in this exercise show simplifications of real solutions.

For example, the concentration of acids varies over many orders of magnitude, and an accurate diagram of a very dilute solution would need to show many thousands of water molecules for each H^+(aq) ion.

Only four types of particle are shown in these diagrams. The following key is used to distinguish between the different particles:

- **HA**
- **H_2O**
- **A^-**
- **H_3O^+**

The size (and shape) of acid molecules varies greatly, and they are often much larger than a water molecule.

Look carefully at the four diagrams on the following pages, and see if you can tell what the differences between them are meant to indicate.

**Diagram 1**
1. What types of particles are shown in the solution represented in this diagram?

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

2. How would you describe this solution?

_________________________________________________________________________
_________________________________________________________________________

Diagram 2

3. What types of particles are shown in the solution represented in this diagram?

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

4. How would you describe this solution (compared to diagram 1)?

_________________________________________________________________________
_________________________________________________________________________
5. What types of particles are shown in the solution represented in this diagram?

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

6. How would you describe this solution (compared to diagrams 1 and 2)?

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
7. What types of particles are shown in the solution represented in this diagram?

_________________________________________________________________________

_________________________________________________________________________

8. How would you describe this solution (compared to diagrams 1-3)?

_________________________________________________________________________

_________________________________________________________________________

9. The four diagrams you were asked to consider are reproduced in miniature below.

1. 

2. 

3. 

4. 

The diagrams are meant to represent a concentrated solution of a strong acid, a dilute solution of a strong acid, a concentrated solution of a weak acid and a dilute solution of a weak acid. Use the table below to show which diagram is meant to represent each of the four solutions – write the number of the appropriate diagram in each box.

<table>
<thead>
<tr>
<th></th>
<th>Strong</th>
<th>Weak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dilute</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Activity 6: Acid-base neutralisation – a microscale titration

A microscale titration apparatus is prepared from pipettes, a syringe and some rubber or plastic tubing. This is then used to carry out a titration by filling the ‘ burette’ with hydrochloric acid and placing 1 cm$^3$ of sodium hydroxide solution in a 10 cm$^3$ beaker. The aim is to calculate the exact concentration of the sodium hydroxide solution.

Apparatus and chemicals

Each working group will require:

Microscale titration apparatus:
Graduated glass pipette (2 cm$^3$)
Pipette (1 cm$^3$) + pipette filler to fit (or a 1 cm$^3$ plastic syringe)
Plastic syringe (10 cm$^3$)
Fine-tip poly(ethene) dropping pipette
Small lengths of rubber, plastic or silicone tubing
Beakers (10 cm$^3$), 2
Clamp stand with two bosses and clamps
Hydrochloric acid, 0.10 mol dm$^{-3}$ (Low hazard at this concentration), about 10 cm$^3$
Sodium hydroxide, approx. 0.1 mol dm$^{-3}$ (Irritant at this concentration), about 10 cm$^3$
Phenolphthalein indicator solution (Highly flammable), a few drops

Procedure

HEALTH & SAFETY: Wear eye protection

a) Clamp the microscale titration apparatus securely in position as in photograph and push the syringe plunger completely down.
b) Fill the apparatus with 0.10 mol dm\(^{-3}\) hydrochloric acid as follows. Put about 5 cm\(^3\) of the acid in a 10 cm\(^3\) beaker and place the tip of the apparatus well down into the solution. Raise the syringe plunger slowly and gently, making sure no air bubbles are drawn in. Fill the pipette exactly to the zero mark. Release the plunger; the level should remain steady.

c) Use the 1 cm\(^3\) pipette and pipette filler to transfer exactly 1.0 cm\(^3\) of the sodium hydroxide solution into a clean 10 cm\(^3\) beaker.

d) Add one drop (no more!) of phenolphthalein indicator solution to the sodium hydroxide solution.

e) Adjust the position of the microscale titration apparatus so that the tip is just below the surface of the sodium hydroxide and indicator solution in the beaker.

f) Titrate the acid solution into the alkali by pressing down on the syringe plunger very gently, swirling to allow each tiny addition to mix and react before adding more.

g) Continue until the colour of the indicator just turns from pink to permanently colourless.

h) Record the volume of hydrochloric acid added at that point.

i) Repeat the titration until you get reproducible measurements – that is, the volume required is the same in successive titrations.

j) Calculate the concentration of the sodium hydroxide solution as follows.

The equation for the neutralisation reaction is:

\[
\text{HCl(aq)} + \text{NaOH(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}
\]

From the equation you can see that one mole of hydrochloric acid reacts with one mole of sodium hydroxide.

1. What was the reliable value for the volume of hydrochloric acid solution needed? Let us call this value \(V\) cm\(^3\).

2. Calculate the number of moles of hydrochloric acid in this volume using the formula: \(V/1000 \times C\), where \(C\) is the concentration of the hydrochloric acid in mol dm\(^{-3}\).

3. How many moles of sodium hydroxide were therefore present in the original 1 cm\(^3\) of sodium hydroxide solution placed in the beaker?

4. Now calculate how many moles of sodium hydroxide would have been present in 1000 cm\(^3\). This is the concentration of the sodium hydroxide solution in mol dm\(^{-3}\).
Activity 7: Acid revision map

- Acid
  - Indigestion
  - Soil
  - pH
  - Indicators
  - Alkalinity
  - Neutral
  - Alkali
  - Base

- Acidic
  - Stomach acid

- Neutral
  - Metal
  - Metal oxide
  - Metal carbonate

- Alkali
  - Rocks
  - Pollution
  - Atmospheric acidity

- Digestion

- Acid soil

- Acidity

- Base

- Rock
Labelling the revision map

You have been given a copy of the acid revision map. This shows some of the important ideas you may have met when you studied acids and bases in your science class. Each line on the map stands for an idea that could be put into a sentence.

The links are not explained on the map. Read through the statements below, and work out which link on the map each sentence is about.

Label each line on the map with the number of the statement – eg 7

1. Acidity is a property of acids.
2. Acids can be identified using indicators.
3. Acidity can be measured using the pH scale.
4. Acidity can be detected using an indicator.
5. Alkalinity is a property of alkalis.
6. Alkalinity can be detected using an indicator.
7. Alkalinity can be measured using the pH scale.
8. Neutral solutions can be identified using indicators.
9. Alkalis can be identified using indicators.
10. Acids are not neutral solutions.
11. Alkalis are not neutral solutions.
12. pH may be found using universal indicator.
13. Acids react with alkalis to give a salt and water.
15. An alkali is a base which dissolves in water.
16. Metal carbonates are bases.
17. Metal carbonates react with acids to give a salt and carbon dioxide.
18. Metal oxides are bases.
19. Metal oxides react with acids to give salts and water.
20. Some metals react with acid to give a salt and hydrogen.
21. Acids in the air cause atmospheric acidity.
22. Atmospheric acidity is increased by some forms of pollution.
23. Atmospheric acidity causes weathering of rocks.
24. Pollution can increase the rate of weathering of rock.
25. Atmospheric acidity causes the corrosion of some metals.
26. Pollution can increase the rate of corrosion of metals.
27. Acid is found in the stomach.
28. Stomach acid helps us digest our food.
29. Too much stomach acid can cause indigestion.
30. Some bases are used to relieve acid indigestion.
31. Some soils contain too much acid for most plants to grow.
32. An alkali is sometimes added to soil to neutralise acidity.

Completing the revision map labels

You have been given a copy of the acid revision map. This shows some of the important ideas you may have met when you studied acids and bases in your science class. Each line on the map stands for an idea that could be put into a sentence.

The links are not explained on the map. Read through the statements below, and work out which link on the map each sentence is about.

However, each sentence has a key word or phrase missing – so you will also need to complete the sentences!

Label each line on the map with the letter of the statement – eg G

A. Acids in the ______________ cause atmospheric acidity.
B. Atmospheric acidity is increased by some forms of ______________.
C. ______________ ______________ causes weathering of rocks.
D. ______________ can increase the rate of weathering of rock.
E. Atmospheric acidity causes the corrosion of some ______________.
F. ______________ can increase the rate of corrosion of metals.
G. ______________ is found in the stomach.
H. ______________ ______________ helps us digest our food.
I. Too much stomach acid can cause ______________.
J. Some bases are used to relieve ______________ ______________.
K. Some ___________ contain too much acid for many plants to grow.

L. ______________ is sometimes added to soil to neutralise acidity.

M. Acids react with ____________ to give a salt and water.

N. Bases react with ________________.

O. An ______________ is a base which dissolves in water.

P. Metal carbonates are ________________.

Q. _____ __________ react with acids to give a salt and carbon dioxide.

R. Metal oxides are ________________.

S. Metal oxides react with ____________ to give salts and water.

T. Some _____________ react with acid to give a salt and hydrogen.

U. Acidity is a property of ________________.

V. Acids can be identified using ________________.

W. Acidity can be measured using the ________________ scale.

X. Acidity can be detected using an ________________.

Y. Alkalinity is a property of ________________.

Z. Alkalinity can be detected using an ________________.

α. Alkalinity can be measured using the ________________ scale.

Ω. Neutral solutions can be identified using ________________.

δ. Alkalis can be identified using ________________.

Φ. Acids are not ________________ solutions.

Σ. Alkalis are not ________________ solutions.

ψ. pH may be found using universal ________________.
Connecting up the revision map

You have been given a copy of an outline of a revision map for the topic of acids. This shows some of the things you may have met when you studied acids and bases in your science class. However the map is not complete!

The boxes on the map need to be connected to show how the ideas are linked.

Instructions

1. Look at the outline map. Find two boxes that you think you can connect.
2. Draw a clear line between the two boxes.
3. Add a label to the line to explain the connection.

4. Repeat for as many connections as you can find.
5. See if you can think of any other boxes that would fit on this revision map. Draw them in.
6. Show the connections for the new boxes in the same ways as above (steps 2 and 3).
## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>The amount of a substance within a known volume of a mixture</td>
</tr>
<tr>
<td>Dissociation</td>
<td>The splitting of a compound into smaller particles</td>
</tr>
<tr>
<td>Effervescent</td>
<td>The release of gas from a solution</td>
</tr>
<tr>
<td>Indicator</td>
<td>A coloured substance that changes colour with hydrogen ion concentration</td>
</tr>
<tr>
<td>Ion</td>
<td>An atom or molecule where the number of electrons is not equal to the number of protons</td>
</tr>
<tr>
<td>Neutralisation</td>
<td>A chemical reaction where an acid and base react together to form a salt</td>
</tr>
<tr>
<td>pH</td>
<td>A measure of the acidity or basicity of an aqueous solution</td>
</tr>
<tr>
<td>Proton donor</td>
<td>An acid donates protons in a reaction</td>
</tr>
<tr>
<td>Mole</td>
<td>A measure of the amount of a substance related to the number of atoms in 12 g of carbon-12.</td>
</tr>
<tr>
<td>Titration</td>
<td>A laboratory method of quantitative chemical analysis that is used to determine the unknown concentration of an identified substance</td>
</tr>
</tbody>
</table>