Acids and Alkalis

Student Notes

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Activity 1: Making a pH indicator

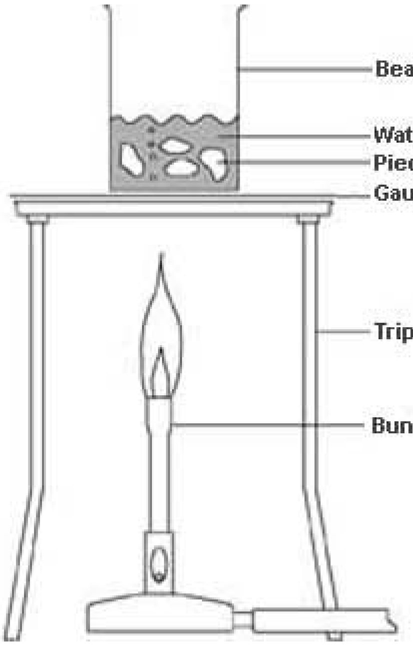
A pH indicator is a substance which has one colour when added to an acidic solution and a different colour when added to an alkaline solution. In this experiment pupils make an indicator from red cabbage. It is also possible to use other materials such as beetroot, berries or flower petals.

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 cm^3)
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

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

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:

Indicator	Colour in acids	Colour in alkalis
Bromothymol blue		
Methyl orange		
Phenolphthalein		

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**
Colour with Bromothymol Blue		
Acid or alkali shown by Bromothymol Blue?		
Colour with Methyl Orange		
Acid or alkali shown by Methyl Orange?		
Colour with Phenolphthaleibn		
Acid or alkali shown by Phenolphthalein?		

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

Record your observations in the table below:

SUBSTANCE	COLOUR SHOWN BY MIXED INDICATORS SOLUTION
Dilute hydrochloric acid	
Boric acid solution	
Tap water	
Sodium bicarbonate solution	
Sodium hydroxide solution	

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_3O^+.
One way to write the equation for an acid 'HA' dissolving in water is:

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

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_3COOH, and 'A^-' would be CH_3COO^-.

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?

____

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____

____

Classifying acid solutions

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

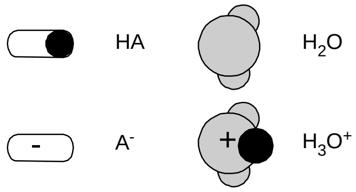
$$HA + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$$

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.

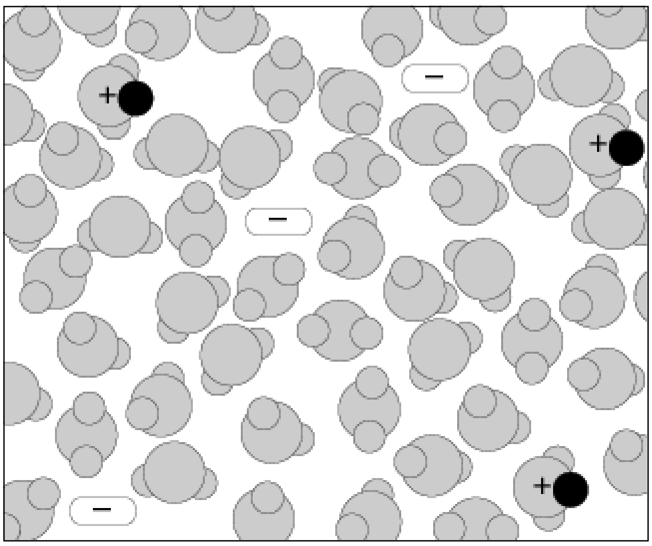
Only four types of particle are shown in these diagrams. The following key is used to distinguish between the different particles:



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?

____

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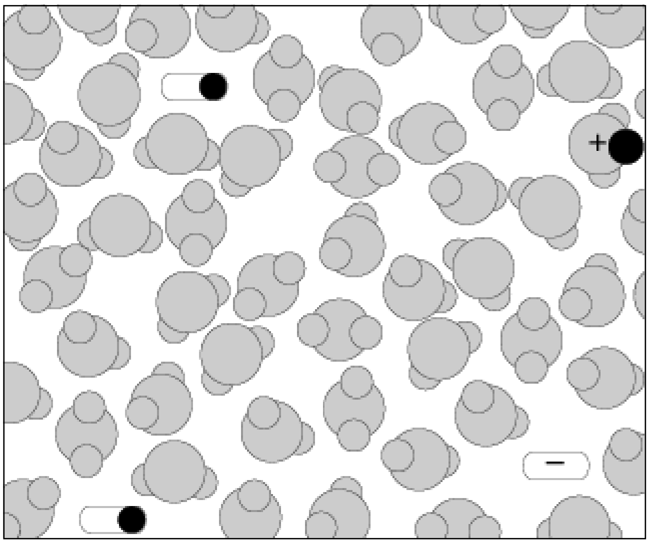
2. How would you describe this solution?

____

____

Diagram 2



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

____

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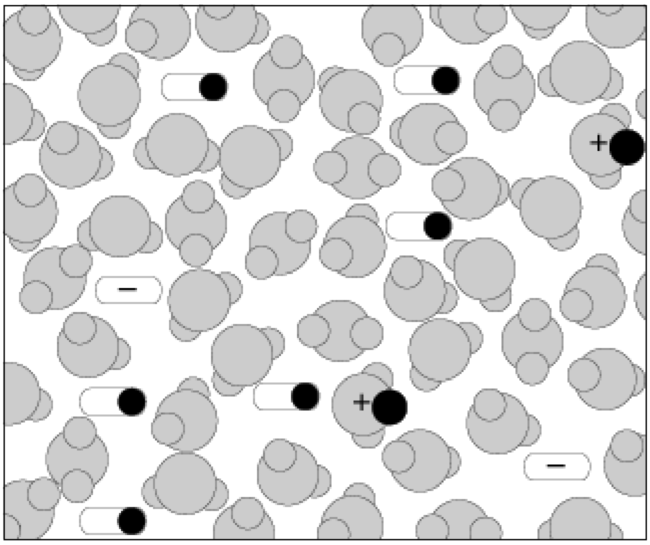
4. How would you describe this solution (compared to diagram 1)?

____

____

Diagram 3



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

____

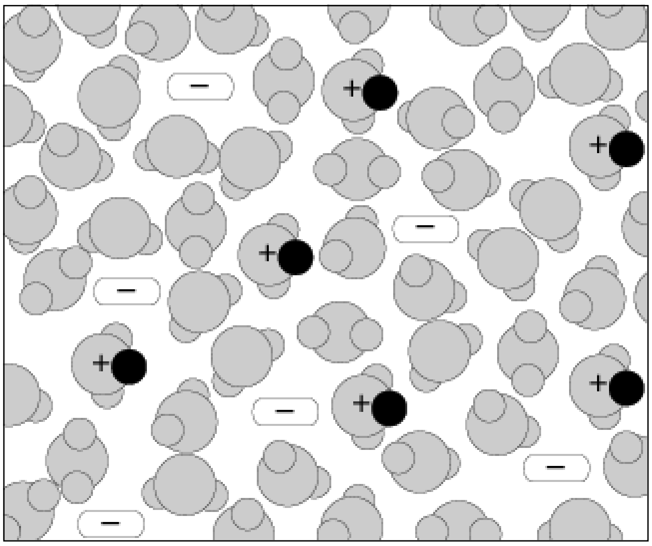
____

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

____

____

Diagram 4



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

____

____

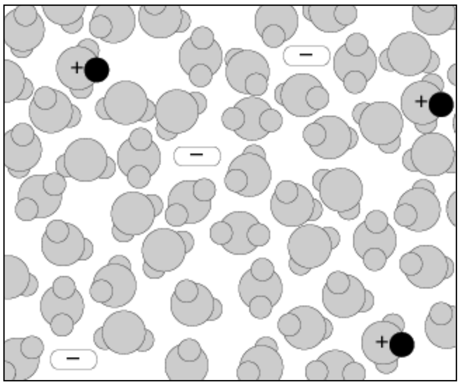
8. How would you describe this solution (compared to diagrams 1-3)?

____

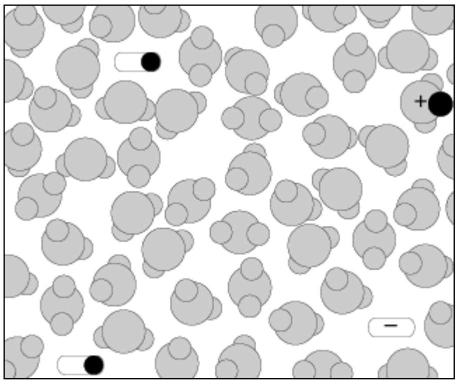
____

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

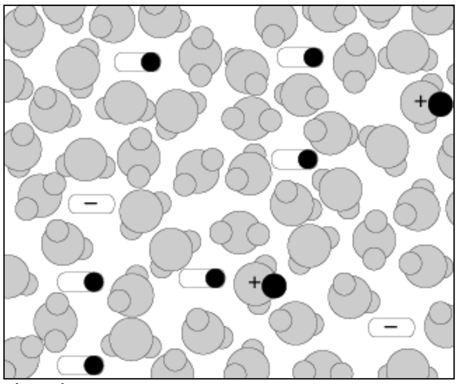
1.



2.



3.



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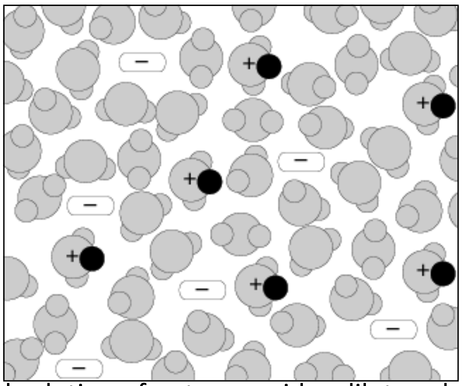


The diagrams are meant to represent a concentrated solution of a strong acid, a dilute solution of a strong acid, a concentrated solution of a weak acid and a dilute solution of a weak acid. Use the table below to show which diagram is meant to represent each of the four solutions – write the number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

	Strong	**Weak**
Concentrated		
Dilute		

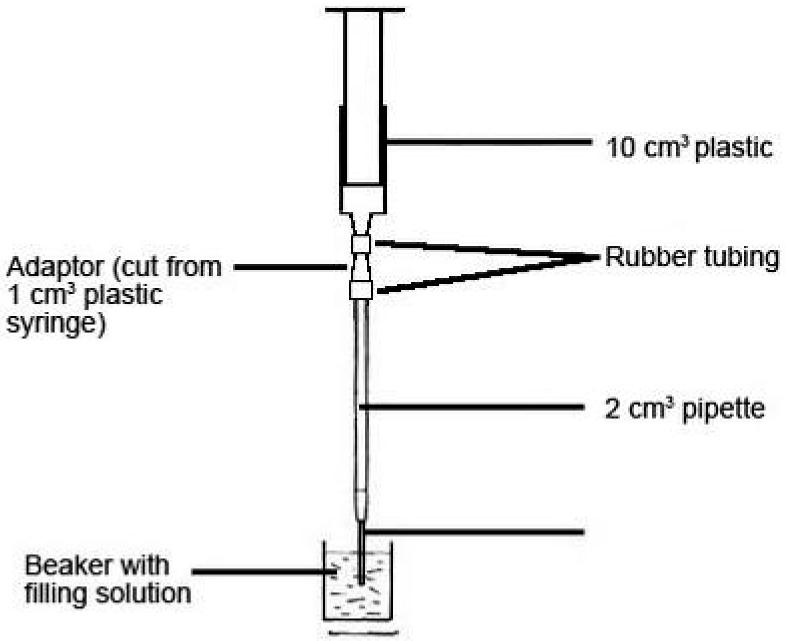
Activity 6: Acid-base neutralisation – a microscale titration

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:

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

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

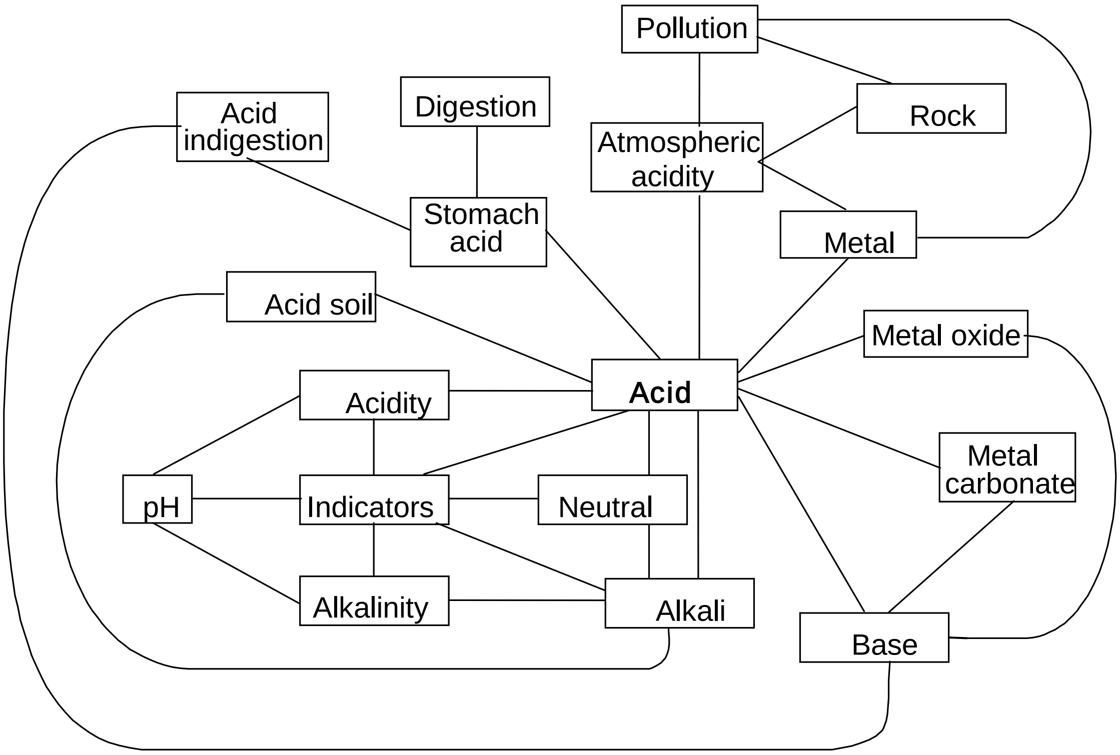
1 What was the reliable value for the volume of hydrochloric acid solution needed? Let us call this value V cm^3.

2 Calculate the number of moles of hydrochloric acid in this volume using the formula: V/1000 x 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?

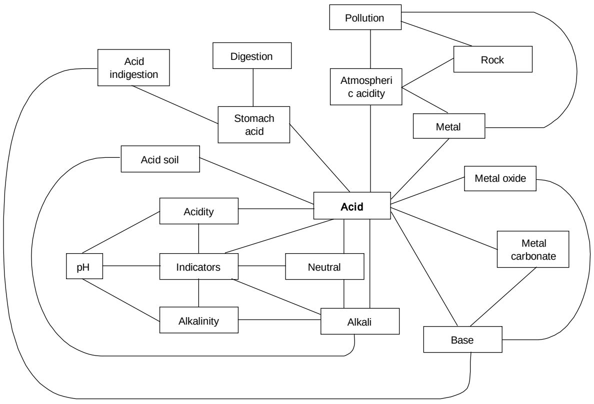
4 Now calculate how many moles of sodium hydroxide would have been present in 1000 cm^3. This is the concentration of the sodium hydroxide solution in mol dm^{-3}.

Activity 7: Acid revision map



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

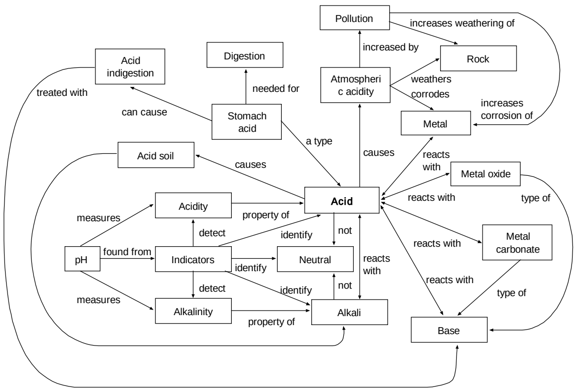
number of the statement – *eg* (7) ————

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.
14. Bases react with acids.
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 _______________.

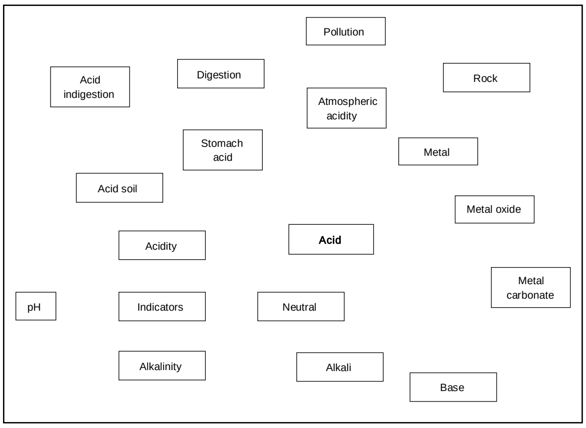
Outline acid revision map

- Pollution
- Acid indigestion
- Digestion
- Rock
- Atmospheric acidity
- Stomach acid
- Metal
- Acid soil
- Metal oxide
- Acidity
- **Acid**
- Metal carbonate
- pH
- Indicators
- Neutral
- Alkalinity
- Alkali
- Base

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.

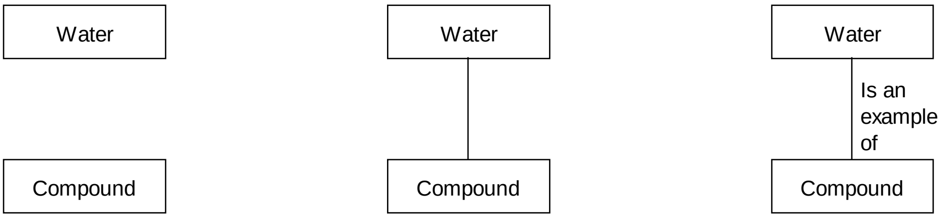


Instructions

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.



Step 1 **Step 2** **Step 3**

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

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

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