Acids, Bases & Indicators

INTRODUCTION TO ACIDS, BASES AND INDICATORS

1.In a school laboratory:
(i)An acid may be defined as a substance that turn litmus red.
(ii)A base may be defined as a substance that turn litmus blue.
Litmus is a lichen found mainly in West Africa. It changes its colour depending on whether the solution it is in, is basic/alkaline or acidic. It is thus able to identify/show whether another substance is an acid, base or neutral.

(iii)An indicator is a substance that shows whether another substance is a base/alkaline,acid or neutral.
2.Common naturally occurring acids include:

Name of acid	Occurrence
1.Citric acid	Found in ripe citrus fruits like passion fruit/oranges/lemon
2.Tartaric acid	Found in grapes/baking powder/health salts
3.Lactic acid	Found in sour milk
4.Ethanoic acid	Found in vinegar
5.Methanoic acid	Present in ants, bees stings
6.Carbonic acid	Used in preservation of fizzy drinks like coke, Lemonade, Fanta
7.Butanoic acid	Present in cheese
8.Tannic acid	Present in tea

3.Most commonly used acids found in a school laboratory are not naturally occurring. They are manufactured. They are called **mineral acids**.
Common mineral acids include:

Name of mineral acid	Common use
Hydrochloric acid (HCl)	Used to clean/pickling surface of metals Is found in the stomach of mammals/human beings
Sulphuric(VI) acid (H_2SO_4)	Used as acid in car battery, making battery, making fertilizers
Nitric(V)acid (HNO_3)	Used in making fertilizers and explosives

4.Mineral acids are manufactured to very high concentration. They are **corrosive** (causes painful wounds on contact with the skin) and attack/reacts with garments/clothes/metals.
In a school laboratory, they are mainly used when added a lot of water. This is called **diluting**. Diluting ensures the concentration of the acid is safely low.

5. Bases are opposite of acids. Most bases do not dissolve in water.
Bases which dissolve in water are called **alkalis**.
Common alkalis include:

Name of alkali	**Common uses**
Sodium hydroxide (NaOH)	Making soaps and detergents
Potassium hydroxide(KOH)	Making soaps and detergents
Ammonia solution(NH_4OH)	Making fertilizers, softening hard water

Common bases (which are not alkali) include:

Name of base	Common name
Magnesium oxide/hydroxide	Anti acid to treat indigestion
Calcium oxide	Making cement and neutralizing soil acidity

6. Indicators are useful in identifying substances which look-alike.
An acid-base indicator is a substance used to identify whether another substance is alkaline or acidic.
An acid-base indicator works by changing to different colours in neutral, acidic and alkaline **solutions/dissolved** in water.

Experiment:To prepare simple acid-base indicator
Procedure
(a)Place some flowers petals in a mortar. Crush them using a pestle. Add a little sand to assist in crushing.
Add about 5cm3 of propanone/ethanol and carefully continue grinding.
Add more 5cm3 of propanone/ethanol and continue until there is enough extract in the mortar.
Filter the extract into a clean 100cm3 beaker.

(b)Place 5cm3 of filtered wood ash, soap solution, ammonia solution, sodium hydroxide, hydrochloric acid, distilled water, sulphuric(VI)acid, sour milk, sodium chloride, toothpaste and calcium hydroxide into separate test tubes.

(c)Put about three drops of the extract in (a)to each test tube in (b). Record the observations made in each case.

Sample observations

Solution mixture	Colour on adding indicator extract	Nature of solution
wood ash	green	Base/alkaline
soap solution	green	Basic/alkaline
ammonia solution	green	Basic/alkaline
sodium hydroxide	green	Basic/alkaline
hydrochloric acid	red	Acidic
distilled water	orange	Neutral
sulphuric(VI)acid	red	Acidic
sour milk	green	Basic/alkaline
sodium chloride	orange	Neutral
toothpaste	green	Basic/alkaline
calcium hydroxide	green	Basic/alkaline
Lemon juice	red	Acidic

The plant extract is able to differentiate between solutions by their nature. It is changing to a similar colour for similar solutions.
(i)Since lemon juice is a known acid, then sulphuric(VI)and hydrochloric acids are similar in nature with lemon juice because the indicator show similar colours. They are acidic in nature.
(ii)Since sodium hydroxide is a known base/alkali, then the green colour of indicator shows an alkaline/basic solution.
(iii) Since pure water is neutral,then the orange colour of indicator shows neutral solutions.
7. In a school laboratory, commercial indicators are used. A commercial indicator is cheap, readily available and easy to store. Common indicators include: Litmus, phenolphthalein, methyl orange, screened methyl orange, bromothymol blue.

Experiment:
Using commercial indicators to determine acidic, basic/alkaline and neutral solutions
Procedure

Place 5cm3 of the solutions in the table below. Add three drops of litmus solution to each solution.
Repeat with phenolphthalein indicator, methyl orange, screened methyl orange and bromothymol blue.

Sample results

Substance/ solution	Indicator used				
	Litmus	**Phenolphthalein**	**Methyl orange**	**Screened methyl orange**	**Bromothymol blue**
wood ash	Blue	Pink	Yellow	Orange	Blue
soap solution	Blue	Pink	Yellow	Orange	Blue
ammonia solution	Blue	Pink	Yellow	Orange	Blue
sodium hydroxide	Blue	Pink	Yellow	Orange	Blue
hydrochloric acid	Red	Colourless	Red	Purple	Orange
distilled water	Colourless	Colourless	Red	Orange	Orange
sulphuric(VI)acid	Red	Colourless	Red	Purple	Orange
sour milk	Blue	Pink	Yellow	Orange	Blue
sodium chloride	Colourless	Colourless	Red	Orange	Orange
toothpaste	Blue	Pink	Yellow	Orange	Blue
calcium hydroxide	Blue	Pink	Yellow	Orange	Blue
Lemon juice	Red	Colourless	Red	Purple	Orange

From the table above, then the colour of indicators in different solution can be summarized.

Indicator	Colour of indicator in		
	Acid	Base/alkali	Neutral
Litmus paper/solution	Red	Blue	Colourless
Methyl orange	Red	Yellow	Red
Screened methyl orange	Purple	Orange	Orange
Phenolphthalein	Colourless	Purple	Colourless
Bromothymol blue	Orange	Blue	Orange

<u>The universal indicator</u>

The universal indicator is a mixture of other indicator dyes. The indicator uses the pH scale.The pH scale shows the **strength** of bases and acids. The pH scale ranges from 1-14.These numbers are called **pH values**:

(i)pH values 1,2,3 shows a substance is **strongly acid**

(ii) pH values 4,5,6 shows a substance is a **weakly acid**

(iii) pH value 7 shows a substance is a **neutral**

(iv)pH values 8,9,10,11 shows a substance is a **weak base/alkali.**

(v)pH values 12,13,14 shows a substance is a strong **base/alkali**

The pH values are determined from a pH chart.The pH chart is a multicoloured paper with each colour corresponding to a pH value.i.e

(i)**red** correspond to pH 1,2,3 showing strongly acidic solutions.

(ii)**Orange/** yellow correspond to pH 4,5,6 showing weakly acidic solutions.

(iii)**Green** correspond to pH 7 showing neutral solutions.

(iv)**Blue** correspond to pH 8,9,10,11 showing weakly alkaline solutions.

(v)**Purple**/**dark blue**correspond to pH 12,13,14 showing strong alkalis.

The universal indicator is available as:

(i) universal indicator **paper**/**pH paper**

(ii) universal indicator **solution.**

When determining the pH of a unknown solution using

(i)pH paper then the pH paper is dipped into the unknown solution.It changes/turn to a certain colour. The new colour is marched/compared to its corresponding one on the pH chart to get the pH value.

(ii) universal indicator **solution** then about 3 drops of the universal indicator **solution** is added into about 5cm3 of the unknown solution in a test tube. It changes/turn to a certain colour. The new colour is marched/compared to its corresponding one on the pH chart to get the pH value.

Experiment:To determine the pH value of some solutions

(a)Place 5cm3 of filtered wood ash, soap solution, ammonia solution, sodium hydroxide, hydrochloric acid, distilled water, sulphuric(VI)acid, sour milk, sodium chloride, toothpaste and calcium hydroxide into separate test tubes.

(b)Put about three drops of universal indicator solution or dip a portion of a piece of pH paper into each. Record the observations made in each case.

(c)Compare the colour in each solution with the colours on the pH chart provided. Determine the pH value of each solution.

Sample observations

Solution mixture	**Colour on the pH paper/adding universal indicator**	**pH value**	**Nature of solution**
wood ash	Blue	8	Weakly alkaline
soap solution	Blue	8	Weakly alkaline
ammonia solution	**green**	8	Weakly alkaline
sodium hydroxide	**Purple**	14	Strongly alkaline
hydrochloric acid	red	1	Strongly acidic
distilled water	green	7	Neutral
sulphuric(VI)acid	**red**	1	Strongly acidic
sour milk	blue	9	Weakly alkaline
sodium chloride	green	7	Neutral
toothpaste	Blue	10	Weakly alkaline
calcium hydroxide	Blue	11	Weakly alkaline
Lemon juice	**Orange**	5	Weakly acidic

Note
1.All the mineral acids Hydrochloric, sulphuric(VI)and nitric(V)acids are strong acids
2.Two alkalis/soluble bases ,sodium hydroxide and potassium hydroxide are strong bases/alkali. Ammonia solution is a weak base/alkali.All other bases are weakly alkaline.
3.Pure/deionized water is a neutral soulution.
4.Common salt/sodium chloride is a neutral salt.
5. When an acid and an alkali/base are mixed, the final product have pH 7 and is neutral.

Properties of acids

(a)Physical properties of acids

1.Acids have a characteristic sour taste
2.Most acids are colourless liquids
3.Mineral acids are odourless. Organic acids have characteristic smell
4.All acids have pH less than 7
5.All acids turn blue litmus paper red,methyl orange red and phenolphthalein colourless.

6.All acids dissolve in water to form an acidic solution.Most do not dissolve in organic solvents like propanone,kerosene,tetrachloromethane,petrol.

(b)Chemical properties of acids.

1. Reaction with metals
All acids react with a reactive metals to form a salt and produce /evolve hydrogen gas.

Metal + Acid -> Salt + Hydrogen gas

Experiment : **reaction of metals with mineral acids**.

(a)Place 5cm3 of dilute hydrochloric acid in a small test tube. Add 1cm length of polished magnesium ribbon. Stopper the test tube using a thump. Light a wooden splint. Place the burning splint on top of the stoppered test tube. Release the thump stopper. Record the observations made.

(b)Repeat the procedure in (a)above using Zinc granules, iron filings, copper turnings, aluminium foil in place of Magnesium ribbon

(c)Repeat the procedure in (a) then (b) using dilute sulphuric(VI) acid in place of dilute hydrochloric acid.

Sample observations

(i)effervescence/bubbles produced/fizzing in all cases except when using copper

(ii)colourless gas produced in all cases except when using copper

(iii)gas produced extinguishes a burning wooden splint with an explosion/pop sound.

Explanation
Some metals react with dilute acids, while others do not. Metals which react with acids produces bubbles of hydrogen gas. Hydrogen gas is a colourless gas that extinguishes a burning splint with a pop sound. This shows acids contain hydrogen gas.
This hydrogen is displaced/removed from the acids by some metals like Magnesium, Zinc, aluminium,iron and sodium.
Some other metals like copper, silver, gold, platinum and mercury are not reactive enough to displace/remove the hydrogen from dilute acids.

Chemical equations

1. Magnesium + Hydrochloric acid -> Magnesium chloride + Hydrogen

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

2. Zinc + Hydrochloric acid -> Zinc chloride + Hydrogen

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

3. Iron + Hydrochloric acid -> Iron(II) chloride + Hydrogen

$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$

4. Aluminium + Hydrochloric acid -> Aluminium chloride + Hydrogen

$2Al(s) + 3HCl(aq) \rightarrow AlCl_3(aq) + 3H_2(g)$

5. Magnesium + Sulphuric(VI)acid -> Magnesium sulphate(VI) + Hydrogen

$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

6. Zinc + Sulphuric(VI)acid -> Zinc sulphate(VI) + Hydrogen

$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$

7. Iron + Sulphuric(VI)acid -> Iron(II) sulphate(VI) + Hydrogen

$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$

8. Aluminium + Sulphuric(VI)acid -> Aluminium sulphate(VI) + Hydrogen

$2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$

2.**Reaction of metal carbonates and hydrogen carbonates with mineral acids**.

All acids react with carbonates and hydrogen carbonates to form a salt, water and produce /evolve carbon (IV)oxide gas.

Metal carbonate + Acid -> Salt + Water + Carbon(IV)oxide gas
Metal hydrogen carbonate + Acid -> Salt + Water + Carbon(IV)oxide gas

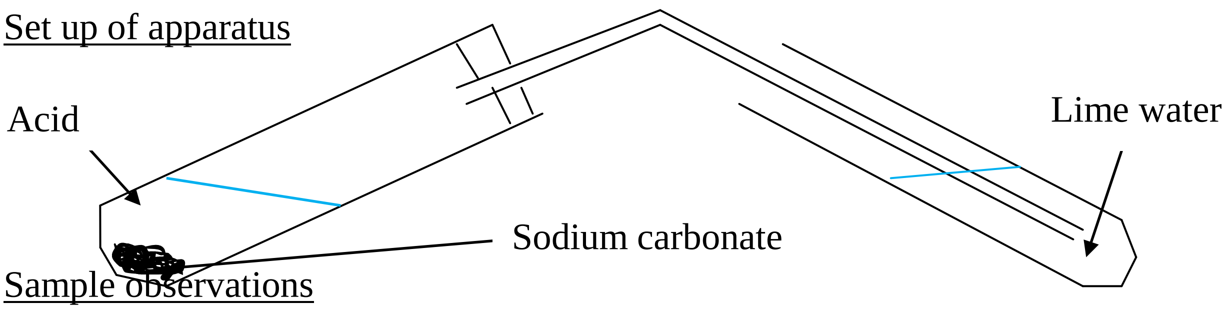
Experiment : **reaction of metal carbonates and hydrogen carbonates with mineral acids.**

(a)Place 5cm3 of dilute hydrochloric acid in a small test tube. Add half spatula full of sodium carbonate. Stopper the test tube using a cork with delivery tube directed into lime water. Record the observations made. Test the gas also with burning splint.

(b)Repeat the procedure in (a) above using Zinc carbonate, Calcium carbonate, copper carbonate, sodium hydrogen carbonate, Potassium hydrogen carbonate in place of Sodium carbonate.

(c)Repeat the procedure in (a) then (b) using dilute sulphuric (VI) acid in place of dilute hydrochloric acid.

Set up of apparatus



Sample observations

(i)effervescence/bubbles produced/fizzing in all cases.
(ii)colourless gas produced in all cases.
(iii)gas produced forms a white precipitate with lime water.

Explanation

All metal carbonate/hydrogen carbonate reacts with dilute acids to produce bubbles of carbon (IV)oxide gas.Carbon(IV)oxide gas is a colourless gas that extinguishes a burning splint. When carbon (IV) oxide gas is bubbled in lime water, a white precipitate is formed.

Chemical equations

1. Sodium carbonate +Hydrochloric acid ->
Sodium chloride + Carbon(IV)Oxide+ Water

$Na_2CO_3(s) + 2HCl\ (aq) \rightarrow 2NaCl\ (aq) + H_2O(g) + CO_2\ (g)$

2. Calcium carbonate +Hydrochloric acid ->
Calcium chloride + Carbon(IV)Oxide+ Water

$CaCO_3(s) + 2HCl\ (aq) \rightarrow CaCl_2\ (aq) + H_2O(g) + CO_2\ (g)$

3. Magnesium carbonate +Hydrochloric acid ->
Magnesium chloride + Carbon(IV)Oxide+ Water

$MgCO_3(s) + 2HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2O(g) + CO_2\ (g)$

4. Copper carbonate +Hydrochloric acid ->
Copper(II) chloride + Carbon(IV)Oxide+ Water

$CuCO_3(s) + 2HCl\ (aq) \rightarrow CuCl_2\ (aq) + H_2O(g) + CO_2\ (g)$

5. Copper carbonate +Sulphuric(VI) acid ->

Copper(II)sulphate(VI) + Carbon(IV)Oxide+ Water

$CuCO_3(s)$ + H_2SO_4 (aq) -> $CuSO_4$ (aq) + $H_2O(g)$ + CO_2 (g)

6. Zinc carbonate +Sulphuric(VI) acid ->

Zinc sulphate(VI) + Carbon(IV)Oxide+ Water

$ZnCO_3(s)$ + H_2SO_4 (aq) -> $ZnSO_4$ (aq) + $H_2O(g)$ + CO_2 (g)

7. Sodium hydrogen carbonate +Sulphuric(VI) acid ->

Sodium sulphate(VI) + Carbon(IV)Oxide+ Water

$NaHCO_3(s)$ + H_2SO_4 (aq) -> Na_2SO_4 (aq) + $H_2O(g)$ + CO_2 (g)

8. Potassium hydrogen carbonate +Sulphuric(VI) acid ->

Potassium sulphate(VI) + Carbon(IV)Oxide+ Water

$KHCO_3(s)$ + H_2SO_4 (aq) -> K_2SO_4 (aq) + $H_2O(g)$ + CO_2 (g)

9. Potassium hydrogen carbonate +Hydrochloric acid ->

Potassium chloride + Carbon(IV)Oxide+ Water

$KHCO_3(s)$ + HCl (aq) -> KCl (aq) + $H_2O(g)$ + CO_2 (g)

10. Sodium hydrogen carbonate +Hydrochloric acid ->

Sodium chloride + Carbon(IV)Oxide+ Water

$NaHCO_3(s)$ + HCl (aq) -> NaCl (aq) + $H_2O(g)$ + CO_2 (g)

3.**Neutralization by bases/alkalis**

All acids react with bases to form a salt and water only. The reaction of an acid with metal oxides/hydroxides(bases) to salt and water only is called neutralization reaction.

Since no effervescence/bubbling/fizzing take place during neutralization:

(i) the reaction with alkalis require a suitable indicator. The colour of the indicator changes when all the acid has reacted with the soluble solution of the alkali (metal oxides/ hydroxides).

(ii) excess of the base is added to ensure all the acid reacts. The excess acid is then filtered off.

Experiment 1 : **reaction of alkali with mineral acids.**

(i)Place about 5cm3 of dilute hydrochloric acid in a boiling tube. Add one drop of phenolphthalein indicator. Using a dropper/teat pipette, add dilute sodium hydroxide dropwise until there is a colour change.
(ii)Repeat the procedure with dilute sulphuric (VI)acid instead of hydrochloric acid.
(iii)Repeat the procedure with potassium hydroxide instead of sodium hydroxide.

Sample observation:
Colour of phenolphthalein change from colourless to **pink** in all cases.

Explanation

Bases/alkalis neutralize acids. Acids and bases/alkalis are colourless. A suitable indicator like phenolphthalein change colour **to pink,**when all the acid has been neutralized by the bases/alkalis. Phenolphthalein change colour **from pink,**to colourless when all the bases/alkalis has been neutralized by the acid.

Chemical equation

Sodium oxide + Hydrochloric acid -> Sodium chloride + Water
$Na_2O(s)$ + HCl -> $NaCl(aq)$ + $H_2O(l)$
Potassium oxide + Hydrochloric acid -> Potassium chloride + Water
$K_2O(s)$ + HCl -> $KCl(aq)$ + $H_2O(l)$

Sodium hydroxide + Hydrochloric acid -> Sodium chloride + Water
$NaOH(s)$ + HCl -> $NaCl(aq)$ + $H_2O(l)$
Ammonia solution + Hydrochloric acid -> Ammonium chloride + Water
$NH_4OH(s)$ + HCl -> $NH_4Cl(aq)$ + $H_2O(l)$

Potassium hydroxide + Hydrochloric acid -> Potassium chloride + Water
$KOH(s)$ + HCl -> $KCl(aq)$ + $H_2O(l)$
Sodium hydroxide + sulphuric(VI)acid -> Sodium sulphate(VI) + Water
$2NaOH(s)$ + H_2SO_4 -> Na_2SO_4 (aq) + $2H_2O(l)$

Potassium hydroxide + sulphuric(VI)acid -> Potassium sulphate(VI) + Water
$2KOH(s)$ + H_2SO_4 -> K_2SO_4 (aq) + $2H_2O(l)$
Ammonia solution + sulphuric(VI)acid -> Ammonium sulphate(VI) + Water
$2NH_4OH(s)$ + H_2SO_4 -> $(NH_4)_2SO_4$ (aq) + $2H_2O(l)$

Magnesium hydroxide + sulphuric(VI)acid -> Magnesium sulphate(VI) + Water
$Mg(OH)_2(s)$ + H_2SO_4 -> $MgSO_4$ (aq) + $2H_2O(l)$
Magnesium hydroxide + Hydrochoric acid -> Magnesium chloride + Water

$$Mg(OH)_2(s) \quad + \quad HCl(aq) \quad \rightarrow \quad MgCl_2\,(aq) \quad + \quad 2H_2O(l)$$

❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖**END**❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖