ACIDS, BASES AND INDICATORS

Contents

Organizer

Objectives

By the end of this Chapter, the learner should be able to:

- Define indicator, acid, base and pH.
- Prepare and use plant extracts as acid–base indicators.
- Describe and use the pH scale.
- Use indicators to identify acids and bases.
- State properties of acids and bases.
- Name the uses of acids and bases.
- State and explain the effects of acids.

ACIDS, BASES AND INDICATORS

Some of the foods that man eats are sour while others are bitter. The sour taste is due to the presence of acids whereas the bitter taste is due to the presence of bases. Examples of substances that contain acids are fruits such as oranges, lemons and sour milk. Examples of substances that contain bases include anti-acid tablets and wood ash solution.

Indicators

Indicators are substances which show different colours when in acids or bases. Such substances are used to classify various substances as either acids or bases.

Simple Acid-Base Indicators: Flower extracts

When flower extracts are used as indicators, solutions of hydrochloric acid, sulphuric acid, orange juice and lemon juice give similar colour changes with the same flower extract.

Lime water, solutions of sodium hydroxide potassium hydroxide, wood ash and baking powder give a similar but different colour.

Water and sugar solution have no effect on flower extracts. They are neutral substances.

The composition of flower extracts continuously changes with time causing the colour of the extract to change. The mixture of the flower extract and acid or base also changes colour with time.

Flower extracts therefore **give inconsistent results** when used as acid-base indicators.

For the best results flower extracts should be used when freshly prepared. Other coloured parts of plants may also be used, for example tradescantia, red cabbage and beetroot.

Commercial Indicators

The commercial acid-base indicators include **litmus indicator** (solution and paper), **phenolphthalein** and **methyl orange.**

Litmus indicator

Litmus indicator is one of the commonly used commercial acid-base indicators. The indicator is also available in paper form as **litmus paper.**

Litmus indicator is **red** in an **acid solution and blue** in a **basic solution.**

Litmus indicator retains its **purple colour** in a **neutral** solution.

Phenolphthalein and methyl orange

Phenolphthalein indicator is **colourless** in **acidic**, **pink** in **basic** and **colourless** in **neutral** solution. **Methyl orange** indicator is **pink** in **acidic**, **yellow** in **basic** and **orange** in **neutral** solution.

These commercial indicators provide no information about the strength of an acid or a base.

Indicator	Colour in:		
	Acid	Base	Neutral
Litmus	Red	Blue	Purple
Phenolphthalein	Colourless	Pink	Colourless
Methyl orange	Pink	Yellow	Orange

Practically Speaking

Classifying substances

Take three test tubes and put 2cm^3 of hydrochloric acid in each. To the first test-tube, add two drops of litmus solution. To the second and third add two drops of phenolphthalein and methyl orange respectively. Record your observation.

Repeat the experiment using water, lemon juice, solutions or suspensions of the following: soap, wood ash, baking powder, anti-acid tablets, toothpaste, sour milk, ammonia, ammonium sulphate, sodium chloride, sodium hydroxide, carbon (IV) oxide (carbon dioxide), sulphur (IV) oxide (sulphur dioxide), sulphuric acid, nitric acid, calcium hydroxide and magnesium oxide.

Classify the substances as acidic, basic or neutral.

Acidic solutions	**Basic solutions**	**Neutral solutions**
Hydrochloric acid	Soap solution	Water
Lemon juice	Wood ash solution	Sodium chloride
Sour milk	Baking powder	
Ammonium sulphate	Anti-acid tablet solution	
Carbon (IV) solution	Toothpaste	
Sulphur dioxide solution	Ammonia solution	
Sulphuric acid	Sodium hydroxide solution	
Nitric acid	Calcium hydroxide solution	
	Magnesium oxide solution	

Universal Indicators and the pH Scale

The **universal** indicator is a **mixture of several indicators.** It exhibits a **range of colours** in acids and in bases **depending on the strength of the solution**. These **shades** of colours are related to a **continuous acid-base scale** called the **pH scale**. The **pH scale** has values that range from **0** to **14.**

1. The pH values of **acids** range from **zero to values just less than seven.** Solutions of sulphuric acid, hydrochloric acid and nitric acid have pH values which range **between 0 to 4** and are **strong acids.**

   Lemon juice and ethanoic acid have pH value which range **between 4 and 7,** and are **weak acids.**

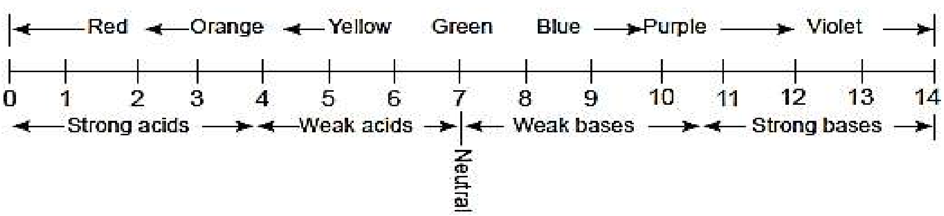
   As the pH values decreases from 7 to 0, the strength of the acids increases.

2. Distilled water and sodium chloride solution have a **pH value of 7.** They are **neither acidic nor basic** and are **neutral.**

3. The pH values of **bases** range **between 7 and 14.** Solutions of ammonia, calcium hydroxide and sodium hydrogen carbonate have pH values **between 7 and 10.** They are **weak bases.**

   Solutions of wood ash, soap, and sodium hydroxide have pH values ranging **from 10 to 14.** They are **strong bases.**

The pH scale is shown alongside.



Acids

An acid is a compound that reacts with metals to form a salt and hydrogen gas.

Metal + Acid ⟶ Metal salt + Hydrogen gas

Properties of Acids

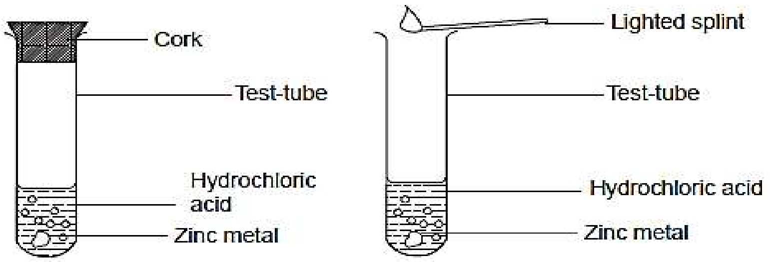
Acids have several properties which are discussed below.

Reactions of Acids with Metals

Acids react with metals to produce a metal salt and hydrogen gas.

Practically Speaking

Put a granule of zinc in two test-tubes. Add 2cm^3 of dilute hydrochloric acid to the first test-tube as shown below.



Record your observations. Repeat the procedure using dilute sulphuric acid in place of dilute hydrochloric acid. Repeat the experiment using clean magnesium ribbon, aluminium foil, iron filings, lead and copper turnings instead of zinc.

Observations and Discussion

When the dilute acids are added to zinc, magnesium, aluminium and iron, **bubbles of a colourless gas are evolved.** The gas produced is hydrogen gas

When dilute sulphuric acid is added to zinc granules, hydrogen gas and zinc sulphate are produced.

The production of bubbles of a gas is referred to as **effervescence.** To identify the gas produced, the gas is tested using a burning splint. A mixture of hydrogen and air burns with a 'pop' sound. This is the test for hydrogen gas.

The reaction can be represented using a word equation.

Zinc + Sulphuric acid ⟶ Zinc sulphate + Hydrogen gas

Similarly, zinc reacts with dilute hydrochloric acid to form zinc chloride and hydrogen gas.

Zinc + hydrochloric acid ⟶ Zinc chloride + Hydrogen gas

Magnesium and aluminium react more vigorously with the acids than zinc.

Magnesium + hydrochloric acid ⟶ Magnesium chloride + Hydrogen gas

Aluminium + Sulphuric acid ⟶ Aluminium sulphate + Hydrogen gas

Side notes

- The reaction of calcium with dilute sulphuric acid slows down and eventually stops due to the formation of insoluble calcium sulphate. The insoluble salt **coats the metal** and prevents further reaction.
- Lead reacts slowly with both hydrochloric and sulphuric acids but each reaction eventually stops due to the formation of **insoluble coating of lead chloride** and lead sulphate respectively.
- Copper **does not react** with either dilute hydrochloric acid or dilute sulphuric acid.
- Very reactive metals like potassium, sodium and calcium **react violently with acids**. These reactions should not be attempted in the laboratory.

The table below shows some salts produced by magnesium with different acids

Dilute acid	Metal	Name of salt
Hydrochloric acid	Magnesium	Magnesium chloride
Sulphuric acid		Magnesium sulphate
Nitric acid		Magnesium nitrate
Carbonic acid		Magnesium carbonate
Phosphoric acid		Magnesium phosphate

Reaction of acids with carbonates and hydrogen carbonates

*Acids react **with carbonates** and **hydrogen carbonates** to produce a **salt, water and carbon (IV) oxide (carbon dioxide).***

The general equations for the reactions are;

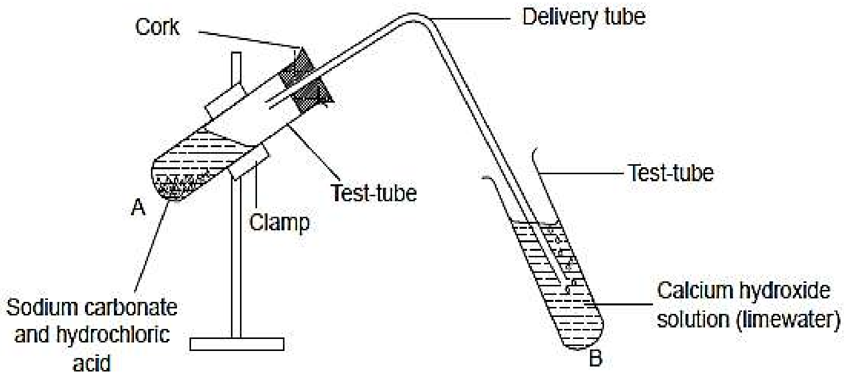
Acid + carbonate ⟶ Salt + Water + Carbon (IV) Oxide

Acid + Hydrogen carbonate ⟶ Salt + Water + Carbon (IV) Oxide

Practically Speaking

Experiment to react acids with carbonates and hydrogen carbonates

Add a spatulaful of sodium carbonate into a test-tube containing about 5cm^3 of dilute hydrochloric acid. Set up the apparatus as shown below.



Record the observation. Repeat the procedure using dilute sulphuric acid and dilute nitric acid in place of hydrochloric acid. Record the observations. Repeat the procedure using calcium carbonate and sodium hydrogen carbonate in place of sodium carbonate.

Observations and Discussion

- When carbonates or hydrogen carbonates are added to dilute acids, effervescence occurs in test tube A as the solid is used up.
- A white precipitate is formed in test tube B

The colourless gas produced is carbon (IV) oxide. When the carbon (IV) oxide gas is bubbled through calcium hydroxide solution (lime water), a white precipitate is formed. This is the test for carbon (IV) oxide. The white precipitate is calcium carbonate.

The following word equations represent some of the reactions between acids and carbonates or hydrogen carbonates.

Sodium carbonate + hydrochloric acid ⟶ Sodium chloride + water + carbon (IV) oxide

Calcium carbonate + nitric acid ⟶ Calcium nitrate + water + carbon (IV) oxide

Copper carbonate + Sulphuric acid ⟶ Copper Sulphate + water + carbon (IV) oxide.

Sodium hydrogen carbonate + hydrochloric acid ⟶ Sodium chloride + water + carbon (IV) oxide

Side notes

The reaction between sulphuric acid and calcium carbonate **stops after a short while** due to the formation of an **insoluble layer of calcium sulphate which stops further reaction.**

Calcium carbonate + Sulphuric acid ⟶ Calcium sulphate (solid) + water + carbon (IV) oxide

Bases

A base is a substance which when reacted with acids forms salt and water as the only products. Metal oxides, metal hydroxides and ammonia solution are bases.

Reactions of Acids with Bases

When acids react with bases, they form a **salt and water** as the only products. Salt and water are **neutral products** hence the reaction is referred to as a **neutralisation reaction.**

Practically Speaking

Experiment to react acids with bases

(a) Measure 10cm^3 of dilute sodium hydroxide solution and put it in a clean conical flask. Add two to three drops of phenolphthalein indicator. Add dilute hydrochloric acid drop by drop, while shaking the conical flask, count the number of drops until the indicator just changes colour. Repeat without adding the indicator. Add the same number of drops of hydrochloric acid to 10 cm^3 of dilute sodium hydroxide. Put the resulting solution in an evaporating dish and heat the solution to saturate it. Allow the saturated solution to cool. Record your observations.

(b) Place a small sample of calcium oxide into a test-tube. Add to it 5cm^3 of dilute nitric acid. Shake the mixture. Repeat the procedure using the following solids in different test-tubes. Zinc oxide, copper (II) oxide, magnesium oxide and lead (II) oxide. Record your observation. Repeat the experiment using dilute hydrochloric acid in place of dilute nitric acid.

Side notes

- Phenolphthalein indicator is used to determine the end of the reaction, **end point.** The indicator is used to determine the **quantity of acid needed to react with 10cm^3 of dilute sodium hydroxide.**
- It is not used in the next reaction to avoid contamination of the product.

Observations and discussion

- The colour of phenolphthalein is pink in basic solution. At the end point, the colour of the indicator in the solution turns from pink to colourless.

Sodium hydroxide reacts with dilute hydrochloric acid to form sodium chloride and water only.

Sodium hydroxide + Hydrochloric acid $\longrightarrow$ Sodium chloride + Water
(base) *(acid)* *(salt)*

The following are the word equations for the reactions between some metal oxides and acids.

Calcium oxide + Hydrochloric acid $\longrightarrow$ Calcium chloride + water

Zinc oxide + Hydrochloric acid $\longrightarrow$ Zinc chloride + water

Magnesium oxide + nitric acid $\longrightarrow$ Magnesium nitrate + water

Lead (II) oxide + nitric acid $\longrightarrow$ Lead nitrate + water

Copper (II) oxide + sulphuric acid $\longrightarrow$ copper sulphate + water

- The table below summarises the properties of acids and bases.

Acids	Bases
Have a sour taste	Have a bitter taste
Have pH values below 7	Have pH values above 7
Turn litmus red	Turn Litmus blue
Turn phenolphthalein colourless	Turn phenolphthalein pink
Turn Methyl orange pink	Turn methyl orange yellow
React with bases to form salt and water only	React with acids to form salt and water only.
React with carbonates to form salt, water and carbon (VI) oxide	
React with metals to produce salt and hydrogen gas	

Effects of Acids on Substances

Industries emit several gases and waste products into the environment leading to environmental pollution. Some of these gases dissolve in rain water to form **acid rain.** This rain reacts with stone work, iron roofs and other metallic surfaces causing damage. This effect is called **corrosion.** When these acidic gases in the atmosphere are inhaled they cause respiratory disorders.

Soil may become acidic due to leaching and water logging. Such soil is unsuitable for the growth of many plants.

Applications of Acids and Bases

Acids and bases have several applications.

Uses of acids

Carbonic Acid is used in aerated drinks to enhance taste.

Hydrochloric acid is used to clean metal surfaces.

Sulphuric acid is used in car batteries, manufacture of ferterlizers, etching of metals, manufacture of paints and detergents.

Nitric acid is used to manufacture of dyes, paints, explosives and fertilizers.

Ethanoic acid and citric acid are used as a flavour in foods.

Uses of bases

Base	Use
Magnesium oxide and hydroxide	Manufacture of anti-acid tablets. Lining of furnaces.
Calcium oxide and hydroxide	Neutralising soil acidity and industrial wastes. Making cement and concrete. Manufacture of toothpaste.
Sodium hydroxide	Manufacture of soap. As a degreasing agent.
Ammonia solution	As a degreasing agent. Manufacture of fertilizers. Manufacture of nitric acid.

Review Exercises

1. (a) Define the term.

(i) acid

(ii) base

(b) In terms of taste, differentiate between acids and bases.

2. Classify the following substances into those that contain acids and those that contain bases: vinegar, milk of magnesia, stomach secretions, lemon Juice, tooth paste and soapy water.

3. State two safety rules that you should follow when using acids and bases.

4. Acids are said to have a sour taste. Why is it advisable to use indicators rather than the sense of taste when testing for acids?

5. Acids can be divided into two groups. State the two groups and give an example of an acid that falls in each group.

6. Citric acid, lactic acid, methanoic acid and hydrochloric acid are found in various substances in plants and animals. State where these acids occur.

7. (a) What is an indicator?

(b) Name three commercial Indicators.

(c) State one advantage of commercial indicators over plant extract indicators.

8. Suggest the pH value of the following solutions:

(a) Dilute hydrochloric acid solution. (b) Wood ash solution.

(c) Sodium hydroxide solution. (d) Orange juice.

9. Describe how you can make acid-base indicators from flower petals and state how you can test it.

10. The table below shows pH values of solutions A, B, C, D and E.

solution	A	B	C	D	E
pH	6.5	2.0	8.5	11.5	7.0

(a) Which solution is likely to be

(i) Rain water? (ii) Wood ash?

(iii) Sodium chloride? (iv) Tooth paste?

(b) Which solution will react with magnesium ribbon most vigorously? Give a reason.

11. (a) What is a universal indicator? __________

(b) State the advantage universal indicator has over the common acid-base indicators.

12. (a) What is an alkali?

(b) Name two examples of alkalis.

13. Name the acids found in

(a) Car battery b) Lemon fruit

(b) Nitrate fertilisers d) Vinegar

14. State the colour of the following in universal indicator.

(a) Ethanoic acid b) Sodium hydroxide

(b) Sulphuric acid d) Ammonium hydroxide

15. Name two common commercial indicators and state their colours in acidic and basic solutions.

16. Tooth pastes contain bases such as calcium hydrogen carbonate. Explain.

17. Although hydrochloric acid in the gastric juice in our stomach helps break down the food we eat, if too much hydrochloric acid is produced, indigestion may result. Antacid tablets containing bases neutralise excess acids in the human stomachs.

(a) Name any two bases found in antacid tablets.

(b) Give the name of the type of reaction that takes place when antacid tablets are swallowed.

(c) Write a word equation for the reaction that occurs in the body during relieving of indigestion.

18. The sourness of a substance is a reasonable guide to Its acidity, since sourness increases with increasing acidity. If solution A is more sour than solution B, then it is likely that: (write true or false)

(a) Solution A has a higher pH than solution B________

(b) Solution A has more hydroxide ions than solution B.___________

(c) Solution B is a stronger acid than solution A._______

(d) Solution A has a higher concentration of hydrogen ions than B.________

19. Arrange the following substances starting with the most acidic to the most basic.

(i) Grape fruit juice of Ph 3.0 (ii) Detergent of pH 10.5

(iii) Gastric juice of pH = 1 .0 (iv) Sea water of pH = 8.5

20. (a) State three properties of a typical acid.

(b) State three properties of a base.

21. Write a word equation for the reaction between dilute sulphuric (VI) acid and the following:

(a) Magnesium metal (b) Copper (II) oxide

(c) Potassium hydroxide (d) Zinc carbonate

22. Give one use of each one of the following:

(a) Dilute hydrochloric acid _______________

(b) Dilute sulphuric (VI) acid _______________

(c) Magnesium hydroxide ________________

In the papers….

1. 2006 Q 19 P1

Give one use of magnesium hydroxide. (1 mark)

2. 2006 Q 24 P1

(a) Complete the table below to show the colour of the given indicator in (1 mark)

Indicator	Colour in	
	Acid solution	Basic solution
Methyl orange		Yellow
Phenolphthalein	Colourless	

(b) How does the pH value of 0.1 M potassium hydroxide solution compare with that of 0.1M aqueous ammonia? Explain. (2 marks)

3. 2007 Q 5 P1
When a student was stung by a nettle plant, a teacher applied an aqueous solution of ammonia to the affected area of the skin and the student was relieved of pain Explain. (2 marks)

4. 2009 Q 22 P1
A student added very dilute sulphuric (VI) acid to four substance and recorded the observations shown in the table below.

Test	Substance	Gas given off
1	Sodium	Yes
2	Iron	No
3	Carbon	Yes
4	Copper	No

For which tests were the observations wrong? Explain. (2 marks)

5. 2009 Q 30 P1
Starting with red roses, describe how;
(a) A solution containing red pigment may be prepared; (1 mark)
(b) The solution can be shown to be an indicator (2 marks)

6. 2011 Q 20 P1
Describe how the PH of anti- acid (Actal) powder can be determined in the Laboratory (2 marks)

7. 2014 Q27 P1
(a) Name a suitable solvent for extracting an indicator from flowers. (1 mark)
(b) Give a reason why the solvent named in (a) above is used (1 mark)

8. 2015 Q15 P1, 2016 Q23 P1
Given the following substances: wood ash, lemon juice and sodium chloride.
(a) Name one commercial indicator that can be used to show whether wood ash, lemon juice and sodium chloride are acidic, basic or neutral. (1 mark)
(b) Classify the substances in (a) above as acids, bases or neutral (2 marks)

Acid	Base	Neutral

9. 2016 Q29 P1
When a student was stung by a nettle plant, a teacher applied an aqueous solution of ammonia to the affected area of the skin and the student was relieved of pain. Explain. (2 marks)

10. 2017 Q14 P1
Using the elements chlorine, calcium and phosphorus:

(a) Select elements that will form an oxide whose aqueous solution has a pH less than 7. (1 mark)

(b) Write an equation for the reaction between calcium oxide and dilute hydrochloric acid. (1 mark)

(c) Give one use of calcium oxide. (1 mark)

11. 2018 Q26 P1
Explain why commercial indicators are preferred to flower extracts as acid-base indicators. (2 marks)

12. 2019 Q6 P1.
A farmer intended to plant cabbages in his farm. He first tested the pH of the soil and found it to be 3.0. If cabbages do well in alkaline soils, explain the advice that would be given to the farmer in order to realise a high yield. (2 marks)

13. 2019 Q16 P1
Complete the following table. (2 mark)

Solution	pH	Nature of solution
H	1.0	
I		Neutral
J		Weak acid
K	13.0	

Explain why a solution of ammonia in methylbenzene has no effects on red litmus paper while in aqueous ammonia red litmus paper turns blue. (1 mark)