10

ACIDS, BASES AND SALTS

After completing this lesson, you will be able to:

This is 13 days lesson (period including homework)

- Define and give examples of Arrhenius acids and bases.
- Use the Bronsted-Lowry theory to classify substances as acids or bases, or as proton donors or proton acceptors.
- Classify substances as Lewis acid or bases.
- Write the equation for self-ionization of water.
- Given the hydrogen ion or hydroxide ion concentration, classify a solution as neutral, acidic, or basic.
- Complete and balance a neutralization reaction.
- Use litmus paper, pH paper and other indicators for measuring pH of solutions.
- Perform acid base titrations and related calculations.
- Identify areas of work for analytical chemists.
- Explain why the quantity of preservatives in food is restricted by government regulations.
- Explain pH-dependent foods.
- Explain process of etching in arts and industry.
- Explain the reactions between industrial pollutants and atmospheric water leading to formation of acids.
- Describe harmful effects of acid rain.
- Explain stomach acidity.

Reading

INTRODUCTION:

You frequently use acids and bases in every aspect of life. For instance, vinegar, aspirin, lemon juice, cola drinks, apple, tomato and toilet bowl cleaner contain acids. Substances such as drain cleaner, antacid tablets, baking powder, washing soda etc. contain bases. You eat and drink certain acids and bases, and your bodies produce them. From “**acid indigestion**” to “**acid rain**” the word **acid** occurs frequently in the news and advertisements.

What is an acid rain? This chapter will enable you to understand which substances are called acids and which are called bases. How they are classified? What happens when an acid reacts with a base? Why do we use lemon juice on fish? In this chapter you will learn some of the chemistry of acids and bases. This will help you to gain a better understanding of these important classes of compounds. What do we mean by the pH of a solution such as that of acid rain? Acids are widely used in the manufacturing of fertilizers and in food industry.

Society Technology and Science

Acid rain can damage trees, kill huge areas of forest. It washes out aluminum ions from the soil. These aluminum ions run into rivers, lakes and ponds. Aluminum is very toxic to fish and other aquatic life. They cannot survive in it and may be killed. Acid rain can also damage buildings and statues. The acid reacts with carbonates in lime stone. The lime stone dissolves and the statue gradually crumbles away. Thus acid rain is an important environmental issue.

Do you know?

Sulphur dioxide and oxides of nitrogen are also produced by smoking of cigarettes. Smokers breathe in a lot of sulphur dioxide. Over long period of time, they have an increased risk of suffering from cold, bronchitis and asthma.

10.1 CONCEPTS OF ACIDS AND BASES

Acids and bases are generally recognized by their characteristic properties. Table 10.1 shows such properties.

Table 10.1 Some characteristic properties of acids and bases

Sr. No.	Property	Acid	Base
1	Taste	Sour	Bitter
2	Effect on blue litmus	Turns red	No effect
3	Effect on red litmus	No effect	Turns blue
4	Effect on skin	Corrosive	Corrosive
5	Electrical conductivity	Aqueous solutions conduct electricity	Aqueous solutions conduct electricity

10.1.1 Arrhenius Concept of Acids and Bases

In 1887, a Swedish chemist Svante Arrhenius proposed the first successful theory of acids and bases. According to this theory

An acid is a substance that ionizes in water to produce H^+ions and a base is a substance that ionizes in water to produces OH^-ions.

For example,

$$HCl_{(g)} \xrightleftharpoons{H_2O} H^+{}_{(aq)} + Cl^-{}_{(aq)}$$

$$NaOH_{(s)} \xrightleftharpoons{H_2O} Na^+{}_{(aq)} + OH^-{}_{(aq)}$$

Which substances in the following reactions are acids or bases?

$$HNO_{3\,(l)} \xrightleftharpoons{H_2O} H^+{}_{(aq)} + NO_3^{-1}{}_{(aq)}$$

$$H_2SO_{4\,(l)} \xrightleftharpoons{H_2O} 2H^+{}_{(aq)} + SO_4^{-2}{}_{(aq)}$$

$$KOH_{(s)} \xrightleftharpoons{H_2O} K^+{}_{(aq)} + OH^-{}_{(aq)}$$

$$NH_4OH_{(aq)} \xrightleftharpoons{H_2O} NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

Table 10.2 shows some common acids and table 10.3 shows some common bases.

Table 10.2 Some Common Acids

Name	Formula	Common use
Hydrochloric acid	HCl	Cleaning of metals, bricks and removing scale from boilers
Nitric acid	HNO_3	Manufacture of fertilizers, explosives
Sulphuric acid	H_2SO_4	Manufacture of many chemicals, drugs, dyes, paints and explosives.
Phosphoric acid	H_3PO_4	Manufacture of fertilizers, acidulant for food

Table 10.3 Some Common Bases

Name	Formula	Common use
Sodium hydroxide	$NaOH$	Soap making, drain cleaners
Potassium hydroxide	KOH	Making liquid soap, shaving cream
Calcium hydroxide	$Ca\ (OH)_2$	Making mortar, plasters, cement
Magnesium hydroxide	$Mg(OH)_2$	Antacid, laxative

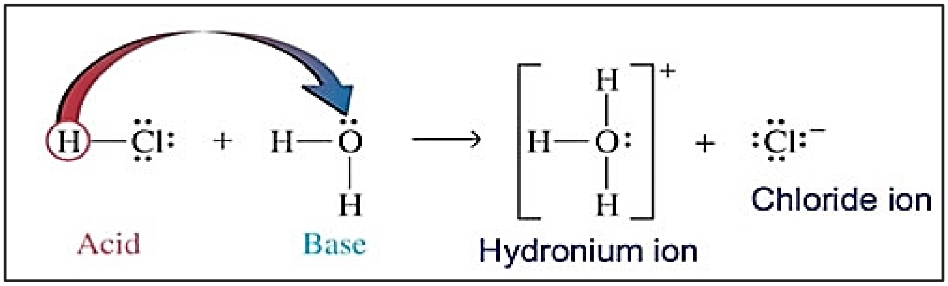
10.1.2 The Bronsted-Lowery Concept of Acids and Bases

Arrhenius theory has its limitations. It applies to aqueous solutions. It does not explain why compounds such as CO_2, SO_2 etc., are acidic. Why substances like NH_3, are bases? There is no H in CO_2 and OH in NH_3.

In 1923 J.N Bronsted and T.M Lowery independently proposed another theory to overcome the shortcomings of Arrhenius theory. This theory is known as **Bronsted-Lowery theory**.

According to this theory **an acid is a proton donor and a base is a proton acceptor**.

Consider the following example



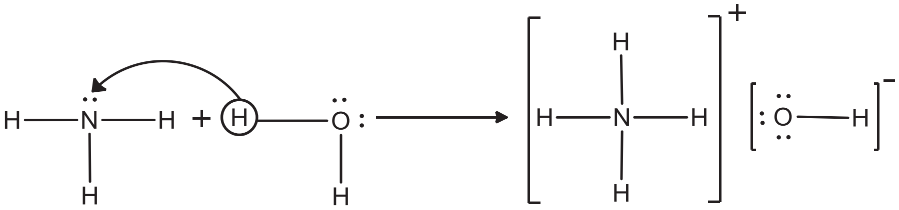
Q.1. Which substance is donating proton? ____

Q. 2. Which substance is accepting proton? ____

Q. 3. Which substance is acid? ____

Q. 4. Which substance is base? ____

Where does the OH^- come from in the ionization of bases such as ammonia? The Arrhenius theory is inadequate to answer this question, but the Bronsted-Lowry theory explains how ammonia acts as a base in water. Ammonia is a gas at room temperature. When it is dissolved in water, the following reaction occurs.



Which substance is donating proton, NH_3 or H_2O? Which substance is proton acceptor? All the acids included in the Arrhenius Theory are also acids in the Bronsted-Lowery Theory. However, all the bases included in Bronsted-Lowery theory except OH^- are not Arrhenius bases. Consider above two examples. In one example, water molecule accepts a proton and in the other water donates a proton. This means water behaves like an acid as well as a base. It is amphoteric in nature. Substances that react with both acids and bases are called amphoteric substances.

Society Technology and Science

Fossils Fuels contain small amounts of sulphur and nitrogen. They produce sulphur dioxide and oxides of nitrogen when the fuel is burned. Large amounts of these oxides are released from coal-burning factories and power stations. They react chemically with the water vapours in clouds and oxygen in the air, forming acids.

$$SO_{2(g)} + \frac{1}{2}O_{2(g)} + H_2O_{(l)} \longrightarrow H_2SO_{4(aq)}$$

$$4NO_{2(g)} + O_{2(g)} + 2H_2O_{(l)} \longrightarrow 4HNO_{3(aq)}$$

These acids mix up with rain drops and fall as acids rain or acid snow.

Example 10.1: Classify substances as acids or bases or as proton donor or proton acceptor

Identify Bronsted-Lowery acids or bases in the following reactions.

$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

$$H_2O + NH_3 \longrightarrow NH_4{}^+ + OH^-$$

Problem solving strategy:

1. An acid is a proton donor. After donating proton, an acid forms a negative ion.
2. A base is a proton acceptor. After accepting proton from an acid it forms a positive ion.

Solution:

1. Because HCl is converted to Cl^- by donating proton, HCl is an acid.
2. Because H_2O accepts the proton that HCl donates and forms H_3O^+, *water* is a base.
3. H_2O is converted to OH^- by donating a proton, so H_2O is an acid. Because NH_3 accepts the proton and forms NH_4^+ so it is a base.

Self Assessment Exercise 10.1

Identify Bronsted acids and Bronsted bases in the following reactions.

1. $H_2SO_4 + H_2O \rightleftharpoons HSO_4^- + H_3O^+$
2. $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$
3. $H_2S + NH_3 \rightleftharpoons NH_4^+ + HS^-$

Reading

10.1.3 Lewis Concept of Acids and Bases:

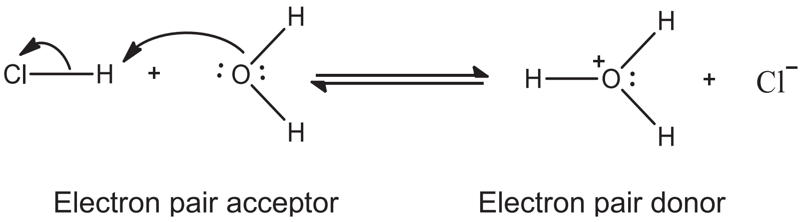
Certain substances like SO_2, CO_2, CaO, BF_3 etc. behave as acids or bases although they do not have ability to donate or accept protons. Nature of such substances cannot be explained by Arrhenius theory or the Bronsted-Lowry theory.

In 1923, G.N Lewis proposed an acid base theory that focuses on reaction. This concept is more general than either the Arrhenius theory or the Bronsted - Lowery theory.

A Lewis acid is substance that can accept a pair of electrons to form a coordinate covalent bond.

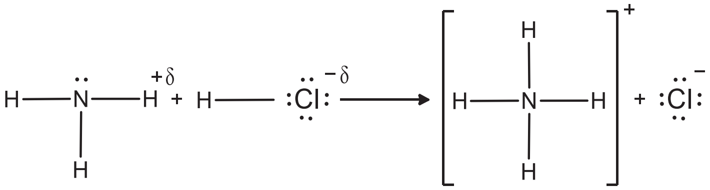
A Lewis base is a substance that can donate a pair of electrons to form a coordinate covalent bond.

In a Lewis acid-base reaction a coordinate covalent bond is formed between the acid and the base. Consider the following reaction.



(i) Which species is donating an electron pair?
(ii) Which species is accepting an electron pair?
(iii) Which species is a Lewis acid?
(iv) Which species is a Lewis base?

This theory can explains gas phase neutralization reactions.

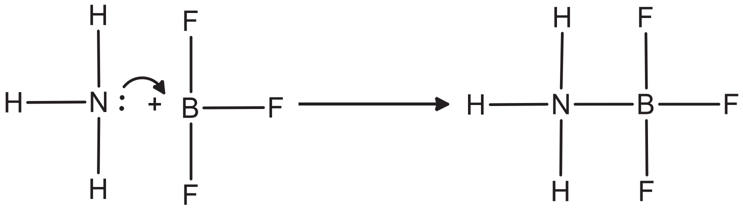


Nitrogen atom in ammonia donates an electron pair to H- atom in HCl. Which species in Lewis acid? HCl or NH_3.

The Lewis structure demands that the central atom or atom of Lewis acid has a deficiency of an electron pair and can accommodate an unshared electron pair. On the other hand, the central atom of a Lewis base has complete octet possessing one or more unshared electron pairs. Hence base has an ability to donate an unshared electron pair.

Example 10.2: Classifying substances as Lewis acids or Lewis bases.

Identify the Lewis acid and Lewis base in the following reactions.

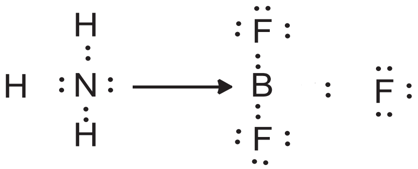


Problem Solving Strategy

1. Draw electronic structures of both the species.
2. Look for the species that has a lone - pair of electron or negative charge. Such a species has complete octet, so it does not need any electron. It can however, donate an electron pair. This species is a Lewis base.
3. Look for the species that can accommodate an electron pair. Such a species has incomplete octet. So this species can accept an electron pair. This species is a Lewis acid.

Solution

(i)



(ii) NH_3 has a lone pair on N-atom. So it is electron pair donor. NH_3 is a Lewis base.

(iii) Boron in BF_3has incomplete octet. It has six electrons (3 electron pairs). So it needs an electron pair to complete its octet. Hence BF_3 is an electron pair accepter or Lewis acid.

Self Assessment Exercise 10.2

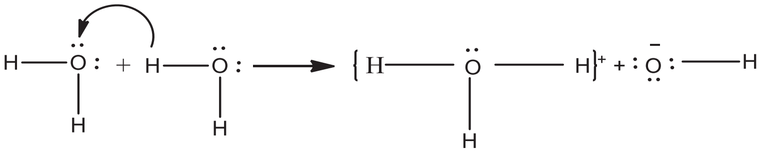
Identify the Lewis acid and the Lewis base in the following examples.

1. $Cl^- + AlCl_3 \longrightarrow [AlCl_4]^-$

2. $H^+ + OH^- \longrightarrow H_2O$

10.2. SELF-IONIZATION OF WATER – THE pH SCALE

Water molecules are highly polar. Occasionally, the collisions between water molecules are energetic enough to transfer a proton from one water molecule to another.



A water molecule that donates or loses a proton becomes a negatively charged hydroxide ion OH^-. The other water molecule which gains or accepts the proton becomes positively charged hydronium ion, H_3O^+.

This reaction can be written as

$$2H_2O \longrightarrow H_3O^+ + OH^-$$

The reaction in which two water molecules produce ions is called as the self-ionization or auto-ionization of water. This reaction can also be written as a simple ionization of water.

$$H_2O_{(l)} \longrightarrow H^+{}_{(aq)} + OH^-{}_{(aq)}$$

Hydrogen ion Hydroxide ion

Water is a weak electrolyte. The self-ionization of water occurs to a very small extent. At 25ºC the experimentally determined concentrations of H^+ ions and OH^- ions are as follows.

$$[H^+] \quad = [OH^-] = 1 \times 10^{-7} M$$

You can write equilibrium constant expression for the self-ionization of water as follows.

$$K_c = \frac{[H^+][OH^-]}{[H_2O]}$$

Since $H_2O$is a weak electrolyte, so the concentration of $[H_2O]$ will remain constant.

$$K_c[H_2O] = [H^+][OH^-]$$

$$K_w = [H^+][OH^-]$$

Where $\mathrm{K_w = K_c[H_2O]}$is called ionization constant for water. It is also called the ion- product for water. For water

$$K_w = (1\times10^{-7})\,(1\times10^{-7}) = 1\times10^{-14} at\ 25^O C$$

in pure water, the concentration of H^+ and OH^- ions are equal.

$$[H^+] = [OH^-] = 1\times10^{-7} at\ \ 25^o C$$

In 1909, the Danish biochemist Soren Sorenson proposed a convenient method to express such a small concentration of H^+ ions and OH^- ions by pH or pOH

pH is defined as the negative logarithm of the molar concentration of H^+ ions in aqueous solutions.

$$pH = -log[H^+]$$

For pure water at 25°C

$[H^+] = 1\times10^{-7}M,\ \ [OH^-] = 1\times10^{-7}M$

$$pH = -log\,(1\times10^{-7}) = 7$$

Thus pH of water is 7. All aqueous solutions with pH= 7 at 25°C are neutral. If pH is less than 7, the solutions become acidic, $[H^+]$ increases and $[OH^-]$ decreases.

Society, Technology and Science

Certain plants grow successfully at a particular pH range

Plant	pH range
Apple	5.5 - 7.0
Broad Bean	6.5 - 7.0
Carrot	6.0 - 7.5
Onion	6.5 - 7.5
Potato	5.5 - 6.5
Tomato	5.5 - 7.0

What is the importance of K_w?

K_w is temperature dependent. In any aqueous solution at 25°C, no matter what does it contain the product of H^+ ion concentration and OH^- ion concentration is always equal to 1.0×10^{-14}. This means that if $[H^+]$ increases, the $[OH^-]$ must decrease so that the product of the two is still 1.0×10^{-14}. What will happen if $[OH^-]$ increases?

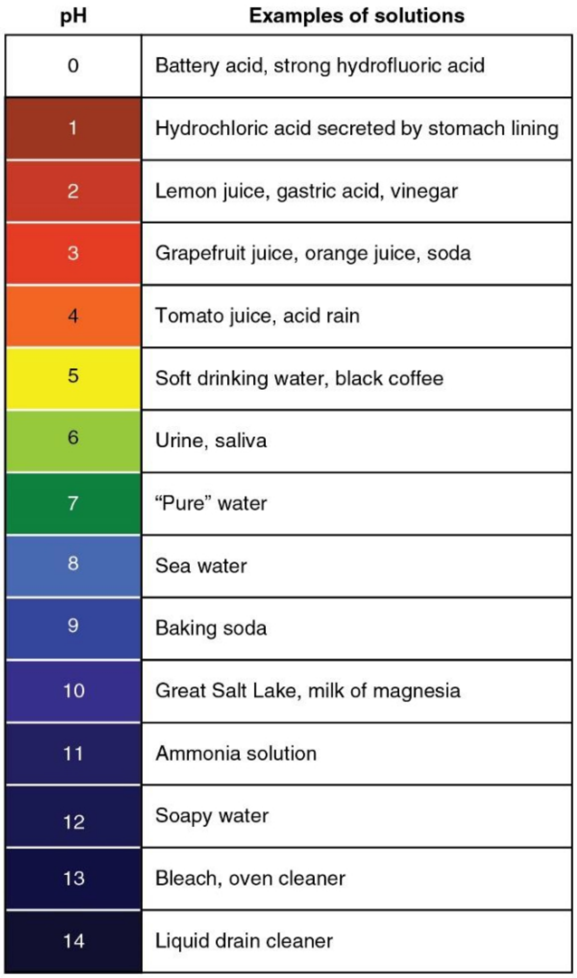
When $[H^+] = [OH^-] = 1\times10^{-7}$, solution is neutral

When $[H^+] > 1\times10^{-7}$, solution is acidic

When $[H^+] < 1\times10^{-7}$, solution is basic

If pH is greater than 7, the solution is basic. As solution becomes basic, $[OH^-]$ increases and $[H^+]$ decreases. If pH is less than 7, the solution is acidic. As solution become acidic, $[H^+]$increases and $[OH^-]$decreases.

Figure 10.1 shows pH scale and pH values of some common substances.



pH	Examples of solutions
0	Battery acid, strong hydrofluoric acid
1	Hydrochloric acid secreted by stomach lining
2	Lemon juice, gastric acid, vinegar
3	Grapefruit juice, orange juice, soda
4	Tomato juice, acid rain
5	Soft drinking water, black coffee
6	Urine, saliva
7	"Pure" water
8	Sea water
9	Baking soda
10	Great Salt Lake, milk of magnesia
11	Ammonia solution
12	Soapy water
13	Bleach, oven cleaner
14	Liquid drain cleaner

Figure 10.1: pH scale and pH values of common substances

Example 10.3: Classifying a solution as neutral, acidic or basic

1. Unrefined hydrochloric acid is used to clean stone buildings and swimming pools. If the [H$^+$] in a solution of HCl is 1×10^{-6} M. Is the solution acidic, basic or neutral?
2. Solution hydroxide (NaOH) is commonly used as a drain cleaner. If the concentration of OH$^-$ in a solution of NaOH is 1.0×10^{-5} M. Is the solution acidic basic or neutral?

Problem Solving Strategy:

1. Compare the given concentrations of $[H^+]$ ions in solution with that of neutral water.
2. If $[OH^-]$ is given, calculate $[H^+]$ from K_w= $[H^+][OH^-]$.

3. Remember that

If $[H^+] = [OH^-] = 1 \times 10^{-7}$ solution is neutral.
If $[H^+] > 1 \times 10^{-7}$, solution is acidic.
If $[H^+] < 1 \times 10^{-7}$, solution is basic.

Solution:

1. $[H^+] = 1.0 \times 10^{-6}M > 1.0 \times 10^{-7}$ M, the solution is acidic.
2. $[OH^-] = 1.0 \times 10^{-5}M$

$[H^+]$ = ?
$K_w = [H^+][OH^-]$.

$$1.0 \times 10^{-14} = [H^+]1.0 \times 10^{-5}$$

$[H^+] = 1.0 \times 10^{-9}M$
Because $1.0 \times 10^{-9}M < 1.0 \times 10^{-7}M$, the solution is basic.

Self Assessment Exercise 10.3

1. A soft drink has $[H^+] = 3 \times 10^{-3}M$. Is the drink acidic drink neutral or basic?
2. Ordinary vinegar is approximately 1M CH_3COOH. Concentration of H^+ in it is 4.2×10^{-3} M. Is vinegar acidic, basic or neutral?
3. A student determines the $[OH^-]$ of milk of magnesia, a suspension of solid magnesium hydroxide in its saturated solution and obtains a value of 4.2×10^{-3}M. Is the solution acidic, basic or neutral?

Reading

10.2.1 The pH Scale

Chemists use a number scale from 0 to 14 to describe the concentration of H^+ions in a solution. It is known as pH scale. Figure 10.1 shows pH scale and pH values of some common substances.

- A pH of 7 indicates a neutral solution.
- Acids have pH less than 7.
- Bases have pH greater than 7.

Important Information

The optimum pH range of a swimming pool is 7.2 to 7.6 because in human tears, when the pH is outside this range, eye irritation can occur.

Teacher's Point

Teacher may give examples of applications of pH in daily life.

Measurement of pH

Scientist use different methods to measure pH of a solution. pH paper or universal indicator paper is used to measure pH of a solution. For this purpose pH paper is dipped in the solution. The colour that develops on the pH paper is compared to the colour corresponding to a known pH on the chart. Each colour is linked to a specific pH value. (Figure 10.2)

Figure 10.2: Colours of pH paper or universal indicator

One of the most commonly used methods in chemistry laboratory is the use of litmus paper. It is used to give a general indication of whether a solution is acidic or basic. Litmus paper may be red or blue. An acid turns blue litmus paper into red. A base turns red litmus paper into blue.

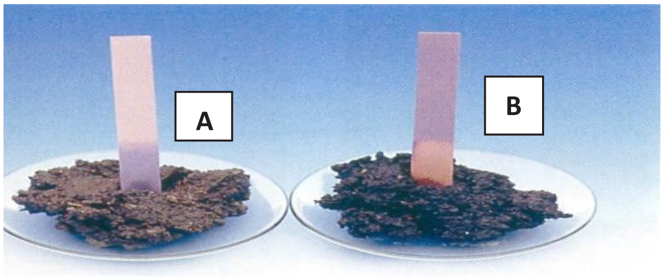


Figure 10.3: The soil sample A turns red litmus blue. The soil sample B turns blue litmus red. Which soil is acidic? Which soil is basic?

Society, Technology and Science

Acidity of stomach

The main component of digestive or gastric juice in the stomach is hydrochloric acid. Almost two litre of it is secreted each day by gastric glands. However sometimes too much acid is secreted in the stomach which causes indigestion. This is called acidity of the stomach.

Acid - base indicators are also used to estimate the pH of a solution. Indicators are intensely colored organic compounds. They change colour within small pH change and indicate the pH of solution by the colour. We add few drops of an indicator to an aqueous solution of unknown pH and measure pH of the solution from the resulting colour. (Figure 10.5)

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Analytical chemist measures pH of solutions. pH measurement has valuable applications. For instance, it helps analytical chemist to **(i)** to create soil conditions ideal for plant growth **(ii)** medical diagnosis**(iii)** maintaining the correct acid-base balance in swimming pools**(iv)** electroplating **(v)** manufacture of medicine etc. tap water and waste water.

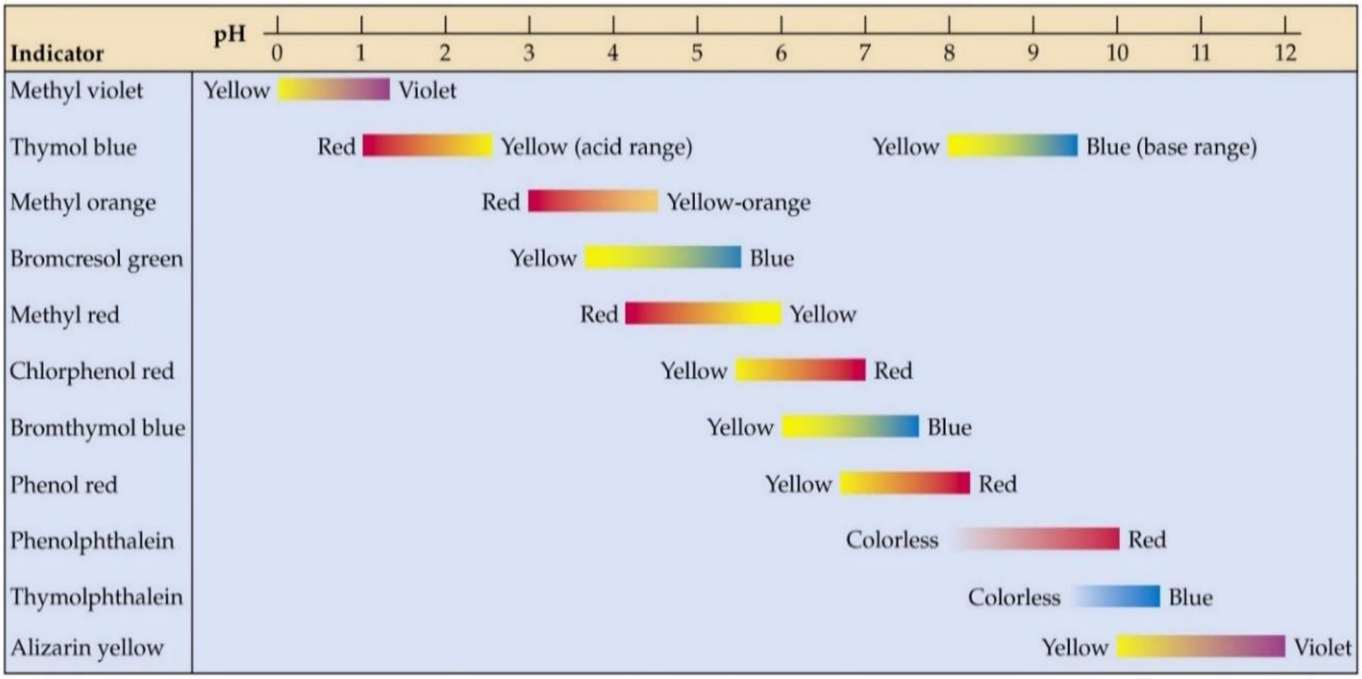

Figure 10.5 Colour changes of some acid base indicators

Methyl red changes color from red to yellow at pH 5. At what pH stage phenolphthalein changes its colour? At what pH stage bromothymol blue changes colour from yellow to blue?

Self Assessment Exercise 10.4

1. Write names of three acid - base indicators.
2. What is the colour of methyl red in solution of (i) pH =4 (ii) pH=9?
3. Bromothymol blue added to a solution imparts blue colour,
4. What is the pH of this solution? pH = 5 or 9

Reading

Table 10.3 pH ranges of some common indicators

Indicator	pH at which colour changes	Colour in acidic solution	Colour in basic solution
Methyl red	5.5	Red	yellow
Bromothymol blue	7	Yellow.	Blue
Phenolphthalein	9	Colourless	Pink

Activity 10.1

Use litmus paper, pH paper and other indicators for measuring pH of solutions

You will need:

- Lemon juice
- Vinegar
- Soap solution
- HCl solution
- NaOH solution

Use of litmus paper: Carry out the following

- Take each solution in separate beakers and write the name of each solution on each beaker.
- Take about 2-3 cm^3 of each solution in separate test tubes and dip red and blue litmus paper in each solution.
- Note the colour change in each case and record.

Result: This test will classify each solution as acid or base or has pH less than 7 or greater.

Use of pH paper:

- Take about 2-3 cm^3 each solution in separate test tubes and dip pH paper in each solution.
- Note the colour developed on pH paper.

Now compare this colour with the pH scale given in figure 10.2 and find pH of solution.

Complete the following table

Substance	pH
Lemon juice	
Vinegar	
Soap solution	
HCl solution	
NaOH solution	

Use of methyl orange

- Take about 2-3 cm^3 of each solution in separate test tubes and add 1-2 drops of methyl orange in each test tube and note the colour of solution.

Key:

Yellow colour indicates pH > 4

Red Colour indicates pH< 4

Complete the following table,

Substance	Colour of methyl orange	pH
Lemon juice		
Vinegar		
Soap solution		
HCl solution		
NaOH solution		

Society, Technology and Science

Etching is an art that uses acid to carve patterns into metal, glass and other materials. For this a piece of metal or glass is covered with wax, and then a design is etched on to the plate through the wax. The plate is then dipped into a tank of acid. The acid eats away at the exposed portion, which leaves behind textured mark. The plate is then taken out of the acid and cleaned. Ink can also be applied on etching to create colourful design.

SKILLS

Activity 10.2: Perform acid base titration and related calculations.

Activity 10.2

To standardize the given solution of hydrochloric acid

Note: Perform this activity in chemistry laboratory.

You will need:

- Burette, Pipette, burette stand, beakers, conical flash, glass rod.
- Standard 0.1M NaOH solution and phenolphthalein.

Chemical equation

$$HCl_{(aq)} + NaOH_{(aq)} \xrightarrow{\qquad} NaCl_{(aq)} + H_2O_{(l)}$$

n_1 = 1 mole n_2 = 1 mole

Carry out the following:

- Fit up a clean burette in the burette stand vertically.
- Fill burette with HCl solution up to zero mark.
- Take 10 cm^3 of NaOH solution in a conical flask with the help of pipette.
- Add few drops of phenolphthalein in it as indicator.
- Note the initial reading on the burette.
- Run the acid solution in the conical flask drop by drop, and shake the flask constantly.
- Go on adding the acid solution till the pink colour just disappears.
- Note down the final reading from the burette.
- The difference between the final and initial reading gives the volume of the acid used to neutralize 10.0 cm^3 of NaOH solution.
- Repeat the experiment to get three concordant readings.
- Find the mean volume of HCl solution used.

Observations and calculations

Suppose volume of HCl solution used = $V_1 = 10\ cm^3$

Molarity of HCl solution = $M_1 = ?$

Volume NaOH solution used $= V_2 = 10\ cm^3$

Molarity of NaOH solution $= M_2 = 0.lM$

No. of moles of HCl $= n_1 = 1$

No. of moles of NaOH $= n_2 = 1$

$$\frac{M_1 \times V_1}{n_1} = \frac{M_2 V_2}{n_2}$$

$$\frac{M_1 \times 10}{1} = \frac{0.1 \times 10}{1}$$

$$M_1 = 0.1\ M$$

Result: Molarity of HCl solution is 0.l M

Do you know?

We make use of chemistry when we put lemon juice on fish. The unpleasant fishy odour is due to amines. The citric acid present in lemon juice converts amines to non-volatile salts, thus reducing the odour.

10.3 SALTS

An acid contains replaceable hydrogen atoms. When these are completely or partially replaced by metal atoms, a compound called salt is formed.

$HCl \longrightarrow NaCl$

Replaceable H atom

Metal atom has replaced H- atom

Which is a salt HCl or NaCl?

Salts are ionic compounds. The first part of the name is of the metal ion and second part of the name is of the negative part of the acid. g. Sodium Chloride.

NaCl

The name of metal ion

The part showing which acid was used

Which acid forms$NaNO_3$? Which acid forms $CaSO_4$? Table 10.4 shows some common acids and their salts.

Table 10.4 Some common acids and their salts

Acid	Salt name	Example
Hydrochloric HCl	Chloride Cl^-	$NaCl, KCl, CaCl_2$
Nitric HNO_3	Nitrate NO_3^{-1}	$NaNO_3, KNO_3, Ca(NO_3)_2$
Sulphuric H_2SO_4	Sulphate SO_4^{-2}	$Na_2SO_4, K_2SO_4, CaSO_4$
Phosphoric H_3PO_4	Phosphate PO_4^{-3}	$Na_3PO_4, K_3PO_4, Ca_3(PO_4)_2$

Neutralization is the specific term used for the reaction of acids with bases.

$$Acid + Base \longrightarrow Salt + Water$$

$$\boldsymbol{HCl_{(aq)}} + \boldsymbol{NaOH_{(aq)}} \longrightarrow \boldsymbol{NaCl_{(aq)}} + \boldsymbol{H_2O_{(l)}}$$

Neutralization is the reaction between H^+ ions of an acid and OH^- ions of a base.

$$H^+{}_{(aq)} + OH^-{}_{(aq)} \longrightarrow H_2O_{(l)}$$

Reactions of acids with bases are used in the experimental procedure of titration. You will do this work in your laboratory. (Activity 10.2)

Example 10.4: Writing complete and balanced chemical equation for a neutralization reaction

1. Soda ash, Na_2CO_3 is used to make glass. It can be made by the reaction of carbonic acid $(H_2CO_3)$and Sodium hydroxide$(NaOH)$. Write complete and balanced chemical equation for this neutralization reaction.
2. Barium nitrate $Ba\ (NO_3)_2$is used to produce a green colour in firework. It can be made by the reaction of nitric acid $(HNO_3)$with barium hydroxide, $Ba(OH)_2$. Write complete and balanced chemical equation for this neutralization reaction.

Problem Solving Strategy

1. Write word equation describing the neutralization reaction.
2. Write chemical formulas of the substances involved in the chemical reaction. Salt consists of cations from the base and anions from the acid.
3. During neutralization reaction one H - atom of an acid combines with one OH group of the base to form one water molecule. So, place a suitable number before acid or base to balance H in acid with OH in base.
4. Balance remaining equation by inspection method.
5. Show the state of each of the substance involved.

Solution

1. Carbonic acid + Sodium hydroxide ⟶Sodium carbonate + water

   $H_2CO_3 + NaOH \longrightarrow Na_2CO_3 + H_2O$

   H_2CO_3 contains two neutralizable H-atoms and NaOH contain only one OH. So multiply NaOH by 2.

   $H_2CO_3 + 2NaOH \longrightarrow Na_2CO_3 + H_2O$

   Now balance H-atoms on the right side by placing 2 before H_2O.

   $H_2CO_3 + 2NaOH \longrightarrow Na_2CO_3 + 2H_2O$

   $H_2CO_{3(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2CO_{3(aq)} + 2H_2O_{(l)}$

2. Nitric acid + Barium hydroxide ⟶ Barium nitrate + water.

   $HNO_3 + Ba\,(OH)_2 \longrightarrow Ba\,(NO_3)_2 + H_2O$

   HNO_3contains one neutralizable H-atom and $Ba(OH)_2$contains two OH-groups. So multiply $HNO_3$by 2.

   $2HNO_3 + Ba\,(OH)_2 \longrightarrow Ba\,(NO_3)_2 + H_2O$

   Now balance H-atoms on the right side by placing 2 beforeH_2O.

   $2HNO_3 + Ba\,(OH)_2 \longrightarrow Ba\,(NO_3)_2 + 2H_2O$

   $2HNO_{3(aq)} + Ba\,(OH)_{2(aq)} \longrightarrow Ba\,(NO_3)_{2(aq)} + 2\,H_2O_{(l)}$

Self Assessment Exercise 10.5

1. Hydroxides such as $\mathrm{Mg(OH)_2}$ called milk of magnesia is used as antacid. It neutralizes excess stomach acid (HCl). Write complete and balanced chemical equation for this neutralization reaction?
2. Hydrochloric acid (HCl) and Potassium hydroxide (KOH) react and produce potassium chloride. Write complete and balanced chemical equation for this neutralization reaction?
3. Balance following neutralization reactions

(i) $H_2SO_{4(aq)} + NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(l)}$

(ii) $H_3PO_{4(aq)} + NaOH_{(aq)} \longrightarrow Na_3PO_{4(aq)} + H_2O_{(l)}$

Some acids form more than one salts. For example Carbonic acid (H_2CO_3) has two replaceable H-atoms. Its partial neutralization forms hydrogen carbonate. On complete neutralization it forms carbonate.

$$H_2CO_{3(aq)} + NaOH_{(aq)} \longrightarrow NaHCO_{3(aq)} + H_2O_{(l)}$$

$$H_2CO_{3(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2CO_{3(aq)} + H_2O_{(l)}$$

$$H_3PO_{4(aq)} + NaOH_{(aq)} \longrightarrow NaH_2PO_{4\,(aq)} + H_2O_{(l)}$$

A salt containing a replaceable H- atom or formed by partial neutralization of an acid is called **acid salt** whereas a salt which is formed by the complete neutralization of an acid is called a **normal salt.**

Which salt is acid salt, $NaHCO_3 or\ Na_2CO_3$?

Which salt is normal salt, $NaHCO_3 or\ Na_2CO_3$?

Phosphoric acid (H_3PO_4) has three replaceable H-atoms, it forms three series of salts,$NaH_2PO_4, Na_2HPO_4, Na_3PO_4$. Which of these salts is/are acid salt?

A salt containing replaceable OH group or formed by the partial neutralization of a polyhydroxy base is called as basic salt.

$$\boldsymbol{Zn(OH)_{2(aq)} + HCl_{(aq)} \longrightarrow Zn(OH)Cl_{(aq)} + H_2O}$$

$$\boldsymbol{Pb(OH)_{2(aq)} + CH_3COOH_{(aq)} \longrightarrow Pb(OH)CH_3COO_{(aq)} + H_2O}$$

Self Assessment Exercise 10.7

Classify following salts as normal or acid salt.

(a) $NaHSO_4$
(b) Na_2SO_4
(c) $KHCO_3$
(d) K_2CO_3

Reading

10.3.1 Methods for making salt

There are five methods for making salts.

1. $\boldsymbol{Acid + Base \longrightarrow Salt + Water}$

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

2. $\boldsymbol{Acid + Metal\ oxide \longrightarrow salt + water}$

$$H_2SO_{4(aq)} + CuO_{(s)} \longrightarrow CuSO_{4(aq)} + H_2O_{(l)}$$

3. $\boldsymbol{Acid + Metal \longrightarrow Salt + Hydrogen}$

$$2HCl_{(aq)} + Mg_{(s)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$$

4. $\boldsymbol{Acid + Metal\ carbonate \longrightarrow Salt + Carbon\ dioxide + water}$

$$HCl_{(aq)} + CaCO_{3(s)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

5. $\boldsymbol{Salt_{(aq)} + Salt_{(aq)} \longrightarrow Salt_{(s)} + Salt_{(aq)}}$

$$AgNO_{3(aq)} + NaCl_{(aq)} \longrightarrow AgCl_{(s)} + NaNO_{3(aq)}$$

10.3 USES OF SALTS

Food preservation keeps food from spoiling and allows it to be stored for later use. Ancient methods for preserving include, drying fruits and vegetables, salting, boiling etc. Today, methods for preserving food also include the addition of preservatives. They are inhibitors of physical and chemical processes that cause food to spoil. Many foods are grown or produced in one location and then sent across the country or even overseas. Without preservatives, these foods would spoil long before they reach their destinations. Many salts such as sulphites and benzoates are being used in food for thousands of years.

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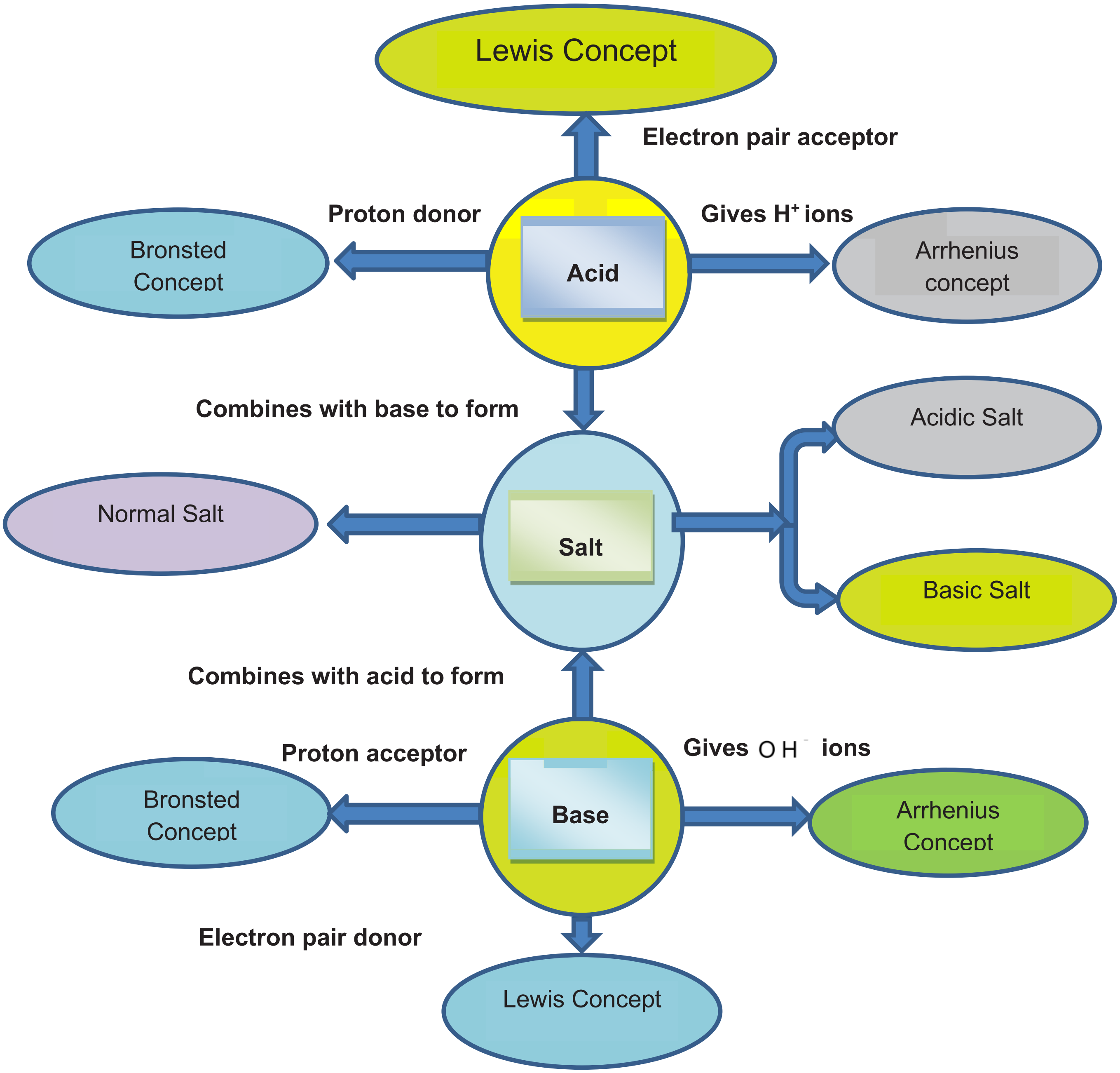
Preservatives in food are designed to prevent bacteria growth and spoilage. But sometimes they can affect your health. Some preservatives may cause breathing difficulties, can weaken heart tissues and can transform into carcinogens.

Many people are allergic or sensitive to preservatives. Some preservatives are safe in small amount and toxic in larger amounts. Hence, Food and Drug Administration Department is given the responsibility for approving the safety and use of preservatives. Government regulations restrict the quantity of preservatives in food.

Concepts in brief



Key Points

- According to Arrhenius theory, an acid is a substance that ionizes in water to produce H^+ ions and a base is a substance that ionizes in water to produce OH^- ions.
- A Bronsted-Lowry acid is a proton donor and a base is a proton acceptor.
- A Lewis acid is a substance that can accept a pair of electrons to form a coordinate covalent bond.
- A Lewis base is a substance that can donate a pair of electrons to form a coordinate covalent bond.
- The reaction in which two water molecules react to produce ions is called as self-ionization of water.
- Ionization constant for water is also called as the ion-product constant for water. Its value is $1 \times 10^{-14} at\ 25°C$.
- $If[H^+] = 1 \times\ 10^{-7}M$ solution is neutral
    - $If[H^+] > 1 \times 10^{-7}M$ solution is acidic
    - $If\ [H^+] < 1 \times 10^{-7}M$ solution is basic
- A pH of 7 indicates a neutral solution
- Acids have pH less than 7.
- Bases have pH greater than 7.
- Indicators change colour within a small pH range and indicate the pH of solution by the colour.
- Methyl orange, bromothymol blue and phenolpthalein are common acid-base indicators.
- Salt is an ionic compound formed when replaceable hydrogen atom in an acid is replaced by a metal atom.
- Reaction between an acid and a base is called neutralization reaction.
- Acid salts contain one or more replaceable H-atoms.
- Normal salts are formed by the complete neutralization of acids.

References for additional informations.

- Longman Chemistry for IGCSE.
- IGCSE Chemistry.
- Cambridge IGCSE, Chemistry.
- Theories of Acids and Base Chemi guide.

Review

1. Encircle the Correct answer

(i) Which of the following cannot be classified as Arrhenius acid?

(a) $\boldsymbol{HNO_3}$ (b) $\boldsymbol{H_2CO_3}$

(c) $\boldsymbol{CO_2}$ (d) $\boldsymbol{H_2SO_4}$

(ii) NH_3 cannot be classified as a base by

(a) Lewis theory (b) Bronsted -Lowry theory

(c) Arrhenius theory (d) All of these theories

(iii) Which of the following is a Lewis base?

(a) BF_3 (b) HCl

(c) $AlCl_3$ (d) F^-

(iv) Choose Lewis acid

(a) CN^- (b) NH_3

(c) H_2O (d) H^+

(v) A drain cleaner solution contains 1.0x10^{-8} M, OH^- concentration. This Solution is

(a) acidic (b) basic

(c) neutral (d) cannot be predicted

(vi) Milk of magnesia contains $\boldsymbol{Mg(OH)_2}$. It is used as antacid. It neutralizes excess stomach acid. Which salt is formed in this reaction?

(a) $\boldsymbol{MgSO_4}$ (b) $\boldsymbol{MgCO_3}$

(c) $\boldsymbol{MgCl_2}$ (d) MgO

(vii) Ammonia is a base, because it

(a) Ionizes in water to give OH^- ions (b) Contains OH group

(c) Can accept an election pair (d) Can accept proton

(viii) Consider the following reaction?

$$\boldsymbol{H_2O + HCl \rightleftharpoons H_3O^+ + Cl^-}$$

Which species is an electron pair acceptor in this reaction?

(a) H_2O (b) HCl

(c) H_3O^+ (d) none

(ix) In the following reaction which species is donating an electron pair?

$$\boldsymbol{NH_3 + BF_3 \longrightarrow [H_3N - BF_3]}$$

(a) H (b) B

(c) N (d) BF_3

(x) An aqueous solution of NaOH is used as a drain cleaner. If the concentration of OH^- ions in this solution is 1.0 x 10^{-5}M, the concentration of H^+ ions in it would be?

(a) $1.0 \times 10^{-5}M$ (b) $1.0 \times 10^{-7}M$

(c) $1.0 \times 10^{-9}M$ (d) $1.0 \times 10^{-14}M$

2. Give short answers?

(i) Write the equation for the self-ionization of water.

(ii) Define and give examples of Arrhenius acids.

(iii) Why H^+ ion acts as a Lewis acid?

(iv) Why $\boldsymbol{NH_3}$ acts as Bronsted-Lowry base?

(v) Why $\boldsymbol{BF_3}$ acts as Lewis acid?

3. Ammonium hydroxide and nitric acid react and produce ammonium nitrate and water. Write balanced chemical equation for this reaction.

4. Write balanced chemical equations for the following neutralization reactions.

(i) $Sulphuric\ acid + Magnesium\ hydroxide \longrightarrow magnesium\ sulphate + water.$

(ii) $Sulphuric\ acid + Sodium\ hydroxide \longrightarrow Soduimsulphate + water.$

(iii) $Hydrochloric\ acid + calcium\ hydroxide \longrightarrow calcium\ chloride + water$

5. Identify Bronsted –Lowry acids or bases in the following reactions.

(i) $HNO_3 + H_2O \longrightarrow H_3O^+ + NO_3^-$

(ii) $NH_3 + HNO_3 \longrightarrow NH_4NO_3$

6. Identify Lewis acid and Lewis base in the following reactions.

(i) $F^- + BF_3 \longrightarrow [BF_4]^-$

(ii) $H^+ + NH_3 \longrightarrow [NH_4]^+$

(iii) $NH_3 + AlCl_3 \longrightarrow [H_3N - AlCl_3]$

7. Classify the following solutions as acidic, basic or neutral.

(i) $A\ solution\ that\ has\ hydrogen\ ion\ concentration\ 1.0 \times 10^{-3}M.$

(ii) $A\ solution\ that\ has\ hydrogen\ ion\ concentration\ 1.0 \times 10^{-10}M.$

(iii) $A\ solution\ that\ has\ hydroxyl\ ion\ concentration\ 1.0 \times 10^{-3}M.$

(iv) $A\ solution\ that\ has\ hydroxyl\ ion\ concentration\ 1.0 \times 10^{-10}M.$

8. Classify following substance as Lewis acid and bases.

$NH_3,\quad F^-,\quad H_2O:\quad ,\quad BF_3$

9. Give the Bronsted-Lowry definition of an acid. Write an equation that illustrates the definition.

10. Identify Bronsted acids and Bronsted bases in the following reactions.

(i) $CH_3COOH_{(aq)} + H_2O \rightleftharpoons CH_3COO^-{}_{(aq)} + H_3O^+{}_{(aq)}$

(ii) $HCO_3^-{}_{(g)} + H_2O_{(l)} \rightleftharpoons CO_{3(aq)}^{-2} + H_3O_{(aq)}^+$

(iii) $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

(iv) $HCl_{(aq)} + HCO_3^-{}_{(aq)} \rightleftharpoons H_2CO_{3(aq)} + Cl^-{}_{(aq)}$

(v) $HS^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons S^{-2}{}_{(aq)} + H_3O^+{}_{(aq)}$

11. Identify the Lewis acids and the Lewis bases in the following reactions.

(i) $H^+{}_{(aq)} + CN^-{}_{(aq)} \longrightarrow HCN_{(aq)}$

(ii) $B(OH)_{3(s)} + OH^-{}_{(aq)} \longrightarrow B(OH)_4^-{}_{(aq)}$

(iii) $Cu^{+2}{}_{(aq)} + 4NH_{3(aq)} \longrightarrow [Cu(NH_3)_4]^{+2}{}_{(aq)}$

(iv) $OH^-_{(aq)} + Al(OH)_{3(s)} \longrightarrow Al(OH)^-_{4(aq)}$

12. Identify Lewis acids and Lewis bases from the following.

$AlCl_3$, Ag^+, $CH_3{-}\ddot{\underset{..}{O}}H$, $CH_3{-}\ddot{N}H_2$, $FeCl_3$

13. Classify water as proton donor or proton acceptor.

14. Write equations showing the ionization of the following as Arrhenius acids.

(a) $HI_{(aq)}$ (b) $HNO_{2(aq)}$

15. Write equations showing the ionization of the following as Bronsted-Lowry acids.

(a) $HNO_{2(aq)}$ (b) $HCN_{(aq)}$

Think-Tank

16. Compare the relative concentrations of hydrogen ions and hydroxide ions in each kind of solution?

(a) acidic (b) basic (c) neutral

17. Codeine, $C_{18}H_{21}NO_3$ is a commonly prescribed pain killer. It dissolves in water by the following reaction?

$$C_{18}H_{21}NO_3 + H_2O \rightleftharpoons [C_{18}H_{21}HNO_3]^+ + OH^-$$

Differentiate Codeine and water as Bronsted-Lowry acid or base.

18. Examine some ways in which you might determine whether a particular water solution contains an acid or a base.

19. The table below shows the colours of two indicators in acidic and alkaline solutions.

Indicator	Colour in Acidic Solution	Colour in Alkaline Solution
A	Red	Blue
B	Colourless	Red

a) Predict the colour of the indicator A?

i. in a solution of pH 3

ii. in a solution of pH 10

b) Predict the colour of the indicator B in a solution of pH 5?

c) When a few drops of indicator B are placed in a solution X, it turns red immediately. Evaluate the properties of solution X?

20. **Bacteria in our mouth feed on small particles of food stuck to our teeth and change it into acid. A toothpaste of pH 10 can help to prevent the acid from damaging our teeth. Defend the statement.**

21. **Can a substance be a Lewis acid without being a Bronsted-Lowry acid? Argue.**

Project

Examine the labels of at least three antacid preparations. Make a list of the ingredients in each. Write a balanced chemical equation for the neutralization reaction that takes place when these antacids react with HCl in the stomach.