3.1 Acids, Bases and Salts

Syllabus

Acids, Bases and Salts [5 Hrs.]

- Introduction
- Characteristics of acids and bases
- Arrhenius concept of acid and base and its limitations
- Lowry and Brønsted concept of acid and base and its limitations
- Conjugate acid-base pair
- Amphoteric nature of water
- Lewis concept of acid and base and its limitations
- Salt
- Types of salts (normal, acidic and basic)
- pH and POH and their mathematical expression
- pH scale
- prove that pH+ pOH=14
- Simple numerical problem on pH
- Buffer solution with examples and its types (No buffer mechanism is required)

1. Arrhenius Concept of Acid and Base

An acid **is a substance that** gives hydrogen ions **(H^+) when dissolved** in water**.** *e.g.*, $HCl \rightarrow H^+ + Cl^-$

A **base** is a substance that **gives hydroxyl ions** (OH^-) when dissolved **in water.** *e.g.*, $NaOH \rightarrow Na^+ + OH^-$

A **salt** is an ionic compound formed from the positive ion of a base and the negative ion of an acid. *e.g.*, $NaCl \rightarrow Na^+ + Cl^-$

Neutralisation according to Arrhenius: An acid and a base react to form water and a salt:

H^+ (from acid) + OH^- (from base) $\rightarrow H_2O$

Limitations of Arrhenius's Concept

The main limitation is that Arrhenius cannot adequately describe substances that can behave as acids and bases **outside the narrow H+/OH− aqueous framework (**cannot explain acidic/basic behaviour in non-aqueous media).

For example;

a. Cannot explain the basicity of **NH_3** and its organic derivatives, as they do not contain OH^-.

b. **Metal oxides** (CaO, Na_2O) act as bases but do not contain OH^-.

c. **Certain compounds** ($AlCl_3$, BF_3) show acidic nature without having H^+ ions.

*d. Fails to account for the **amphoteric nature** of substances (e.g., Al_2O_3, ZnO)*

Conclusion: The Arrhenius concept is too narrow to explain many acid-base behaviours

1. Discuss the Arrhenius concept of acids and bases with examples. Write its two limitations. [4]
2. What do you mean by acid and base according to the Arrhenius concept? Explain. [3]
3. What do you mean by acid and base according to the Arrhenius concept? Also, explain its limitations. [4]
4. State and explain the Arrhenius concept of acid and base with its limitations. [5]
5. Explain the Arrhenius concept of acid and base with its limitations. [4]
6. What do you mean by acid and base according to the Arrhenius concept? Also mention its limitations. [3+2]
7. Define acid and base in terms of the Arrhenius concept with one example of each. [3]
8. Define acid and base according to the Arrhenius concept. Also mention its limitations. [5]

2. Bronsted–Lowry Concept (Proton Transfer Theory)

- **Acid**: A species that donates protons (H^+) — *proton donor*.
- **Base**: A species that accepts protons(H^+) — *proton acceptor*.

$$\underset{\text{acid}}{HCl} + \underset{\text{base}}{H_2O} \rightleftharpoons \underset{\text{acid}}{H_3O^+} + \underset{\text{base}}{Cl^-}$$

- **Forward reaction:**
  - HCl donates a proton → HCl is the **acid**.
  - H_2O accepts a proton → H_2O is the **base**.
- **Reverse reaction:**
  - H_3O^+ donates a proton → H_3O^+ is the **acid**.
  - Cl^- accepts a proton → Cl^- is the **base**.

Species that tend to give as well as accept a proton are termed amphoteric species or substances. Example: H_2O, HCO_3^-, and HSO_4^- are amphoteric or amphiprotic substances.
Amphoteric is a general term for a substance showing the dual nature of acid and base.

Conjugate acid-base pairs

Conjugate acid base pair

$$\underset{\text{acid 1}}{HCl} + \underset{\text{base 1}}{H_2O} \rightleftharpoons \underset{\text{acid 2}}{H_3O^+} + \underset{\text{base 2}}{Cl^-}$$

Conjugate acid base pair

When an acid donates a proton, the remaining species is its **conjugate base**.
When a base accepts a proton, the new species is its **conjugate acid**.

From the above reaction:

- **HCl (acid)** and **Cl^- (conjugate base)** form one pair.
- **H_2O (base)** and **H_3O^+ (conjugate acid)** form the other pair.

⭐ Easy rule

Acid loses H+ → conjugate base

Base gains H+ → conjugate acid

🧠 **QUICK CHECK**

In the reaction below, identify the acid, base, conjugate acid and conjugate base.

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

Advantages over Arrhenius

1. Works in any solvent (water, alcohol, liquid NH_3) and even in the gas phase.

2. Explains NH_3 as a base (it accepts a proton from water: $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$).
3. Explains H_2O as amphiprotic (can act as an acid or base).
4. Explains metal oxides as bases ($O^{2-} + H_2O \rightarrow 2\,OH^-$, then OH^- accepts protons).

Limitation of Brønsted–Lowry

It still requires **protons**. It cannot explain acid-base reactions that do not involve proton transfer (e.g., $BF_3 + NH_3 \rightarrow F_3B\text{–}NH_3$, or metal ions acting as acids).

9. Explain acid and base on the basis of Lowry and Bronsted concept. [2]
10. State and explain Bronsted and Lowry concept of acid and base. Why water is called amphoteric substance? [5]
11. What is amphoteric substance? Explain the amphoteric nature of water (H_2O). State Bronsted and Lowry concept of acid and base. [1+1+2]
    State and explain Bronsted and Lowry concept of acid and base. [3]

3. Lewis Concept (Electronic Concept)

Acid: A species that accepts a pair of electrons from a base to form a coordinate covalent bond, i.e., an **electron pair acceptor.** An electrophile (electron-loving species) acts as a **Lewis acid**.
Base: A species (atoms, ions, molecules, etc.) that **donates a pair of electrons** to an acid to form a coordinate covalent bond. Nucleophiles (nucleus-loving species) act as Lewis bases.

Example 1: $BF_3 + NH_3$

BF_3 — Boron has an incomplete octet → **Lewis Acid** (electron pair acceptor).

$:NH_3$ — Nitrogen has a lone pair → **Lewis Base** (electron pair donor).

Reaction: $BF_3 + :NH_3 \rightarrow F_3B\text{–}NH_3$ (a coordinate covalent bond forms from N to B)

Example 2: $H^+ + :NH_3$

H^+ — Has an empty 1s orbital → **Lewis Acid**

$:NH_3$ — Lone pair on N → **Lewis Base**

Reaction: $H^+ + :NH_3 \rightarrow NH_4^+$

Merits of the Lewis concept:
1. **Includes non-proton reactions:** Covers coordination chemistry, metal complexes, and many organic reactions (e.g., Friedel-Crafts alkylation using $AlCl_3$ as a Lewis acid).
2. It also includes the basic properties of metallic oxides and the acidic properties of nonmetallic oxides.
3. It can also explain that H^+ and OH^- are Lewis acids and Lewis bases, respectively.
4. **Explains acidity of salts like $AlCl_3$, BF_3, $FeCl_3$:** They are electron-deficient and accept electron pairs

Demerits of Lewis Concept:

1. Fails to arrange the acids and bases according to relative strength.
2. Says a coordinate covalent bond is formed between an acid and a base. However, **strong mineral acids** such as H_2SO_4, HCl, and HNO_3 do not form any coordinate covalent bonds.
3. Most acid-base reactions (e.g., HCl + NaOH in water) are very fast, but forming a coordinate covalent compound is slow. Such a rapid acid-base reaction is not accounted.

Comparison Table

Feature	Arrhenius	Brønsted–Lowry	Lewis
Fundamental process	Ion formation in water	Proton (H^+) transfer	Electron pair transfer
Acid	Gives H^+ in water	Donates H^+	Accepts an electron pair
Base	Gives OH^- in water	Accepts H^+	Donates an electron pair
Main idea	H^+/OH- in water	Proton transfer	Electron-pair transfer
Solvent required?	Only water	Any (or none)	Any (or none)

Summary of Progression

1. **Arrhenius** started the idea: acids give H^+, bases give OH^- in water.
   Problem: Too narrow.
2. **Brønsted–Lowry** expanded: acids donate H^+, bases accept H^+ in any medium.
   Problem: Still requires protons.
3. **Lewis** gave the most general definition: acids accept electron pairs, bases donate electron pairs.
   Problem: Loses quantitative strength ordering.

Each concept is still useful today — just in different contexts. For everyday aqueous chemistry, Arrhenius or Brønsted is fine. For coordination compounds and organic mechanisms, Lewis is essential.

12. What are Lewis acids and bases? Explain with appropriate examples. [1+3]
13. Discuss the Lewis concept of acid and base giving appropriate examples. [1.5+1.5]
14. Explain Lewis acid base concept with example.
15. Define buffer solution. 2
16. Write short notes on: Lowry and Bronsted concept of acid and base 2.5
17. Write short notes on: buffer solution
18. Calculate the pH of: a. 0.001 molar HCl b. 0.005 molar H_2SO_4 [2+2]
19. Calculate the pH of the following solutions: i. 0.5 M H_2SO_4 ii. 0.1 M NaOH [1.5+1.5]
20. 10^{-3} mole of NaOH is dissolved in 10 liters of water. What will be the pH of the solution? [3]
21. Calculate the [H^+] and [OH^-] in a solution in which 2 gram NaOH are dissolved in 2 liter solution. [4]
22. Calculate the [H^+] and [OH^-] in 0.2M HCl solution. [4]
23. Calculate the [H^+] and [OH^-] ion in solution. Of 4 gram sodium hydroxide are dissolved in 2 litre solution.
24. What do you mean by pH scale?

25. Write about types of salt. [2]
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