Analytical Chemistry

VOLUMETRIC ANALYSIS
ACID–BASE TITRATIONS

Sawa University

College of Pharmacology

First Stage

جامعـــــة ســـــاوة الأهلية

كلية الصيدلة

المرحلـــــــــــة الاولى

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المحاضرة الرابعة : الجانب النظري

Introduction to Titration

Titration is one of the most important **quantitative analytical** methods used in chemistry.

The main purpose of titration is to **determine the concentration or amount of an unknown substance** by reacting it with a solution of known concentration.

In titration, we do not measure the analyte directly. Instead, we measure how much titrant reacts with it

Basic Principle of Titration

All titration methods are based on the same basic idea:

1- **A chemical reaction occurs between analyte and titrant.**

2- The reaction must be fast, complete, and stoichiometric

3- The reaction is followed until it is just completed

4- The volume of titrant used gives us the key to calculate the unknown concentration

General Titration Procedure

The general steps of any titration are:

1- **A known volume of analyte is placed in a flask**

2- A suitable indicator is added

3- The titrant is added from a burette gradually

4- Near completion, titrant is added drop by drop

5- The end point is detected by a color change or signal

General Titration Procedure

Steps:

1. Measure a **known** volume of the analyte and transfer it to a conical flask.
2. Add **2–3** drops of a suitable **indicator**.
3. Fill the burette with the **standard titrant**.
4. Add the titrant **slowly** with continuous swirling.
5. Near the **end point**, add the titrant **dropwise**.
6. Stop the titration when a **permanent color change** appears.
7. Record the **final burette reading** and calculate the result.

Note: The **indicator** must change color close to the equivalence point for accurate results.

Types of Titrations

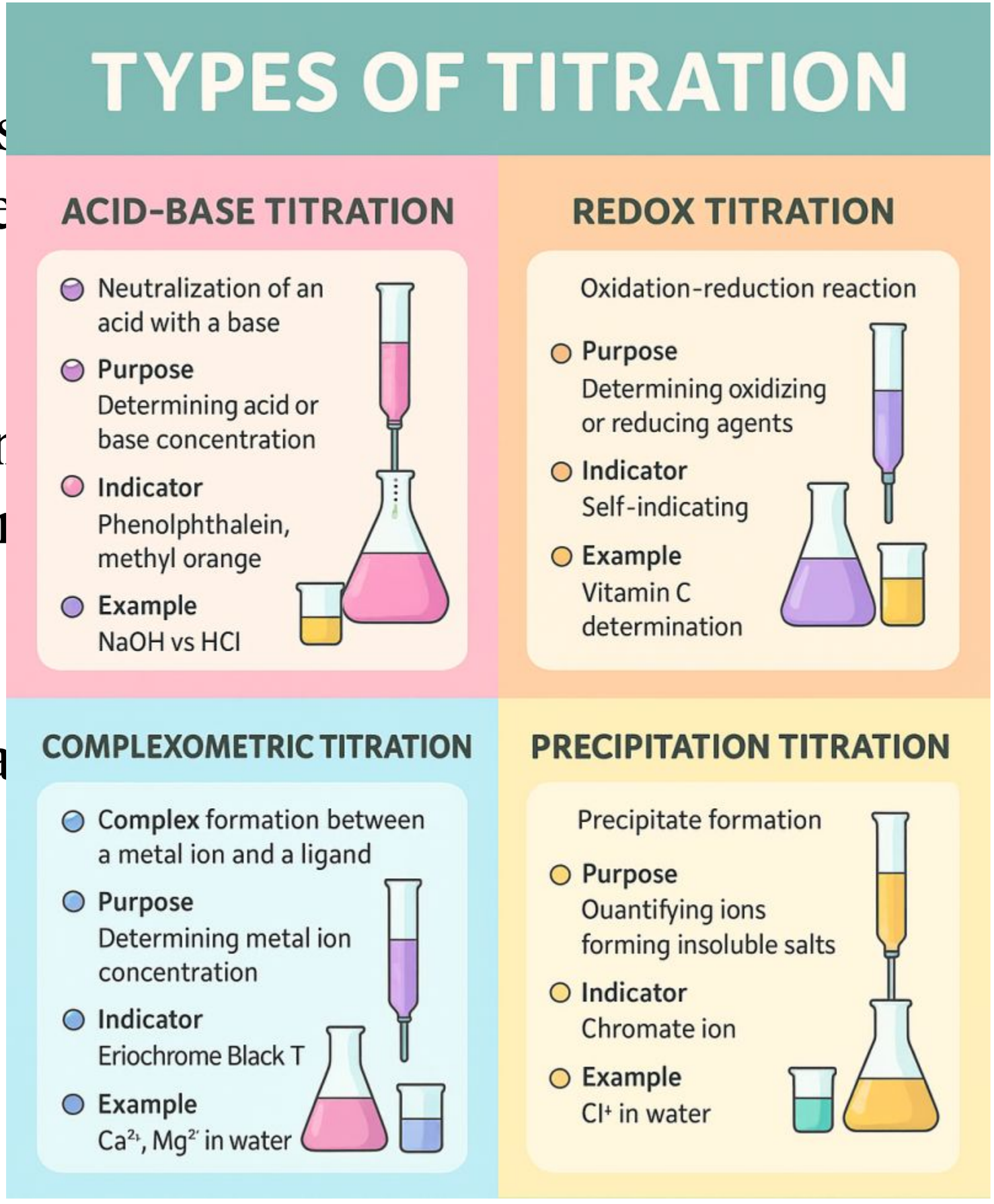
Titration methods are clas
chemical reaction involve

1- Acid–Base titration
(proton transfer)

2- Precipitation titratio
(formation of insoluble pr

3- Redox titration
(electron transfer)

4- **Complexometric titra**
(complex formation)



Acid–Base Titrations

Acid–base titration is based on a neutralization reaction between an acid and a base.

During the titration, hydrogen ions from the acid react with hydroxide ions from the base to form water:

$$H_+ + OH_- \rightarrow H_2O$$

This reaction is fast and goes to completion, making acid–base titrations very accurate

Acid–Base Indicators

Because we cannot see the equivalence point directly, we use indicators.

Acid–base indicators are weak organic acids or bases that change color over a specific pH range.

The indicator must change color close to the equivalence point

Acid–Base Titrations

Mechanism of Indicator Action

The color change of an indicator is due to chemical equilibrium:

$$HIn \rightleftharpoons H_+ + In^-$$

- HIn has one color
- In^- has a different color

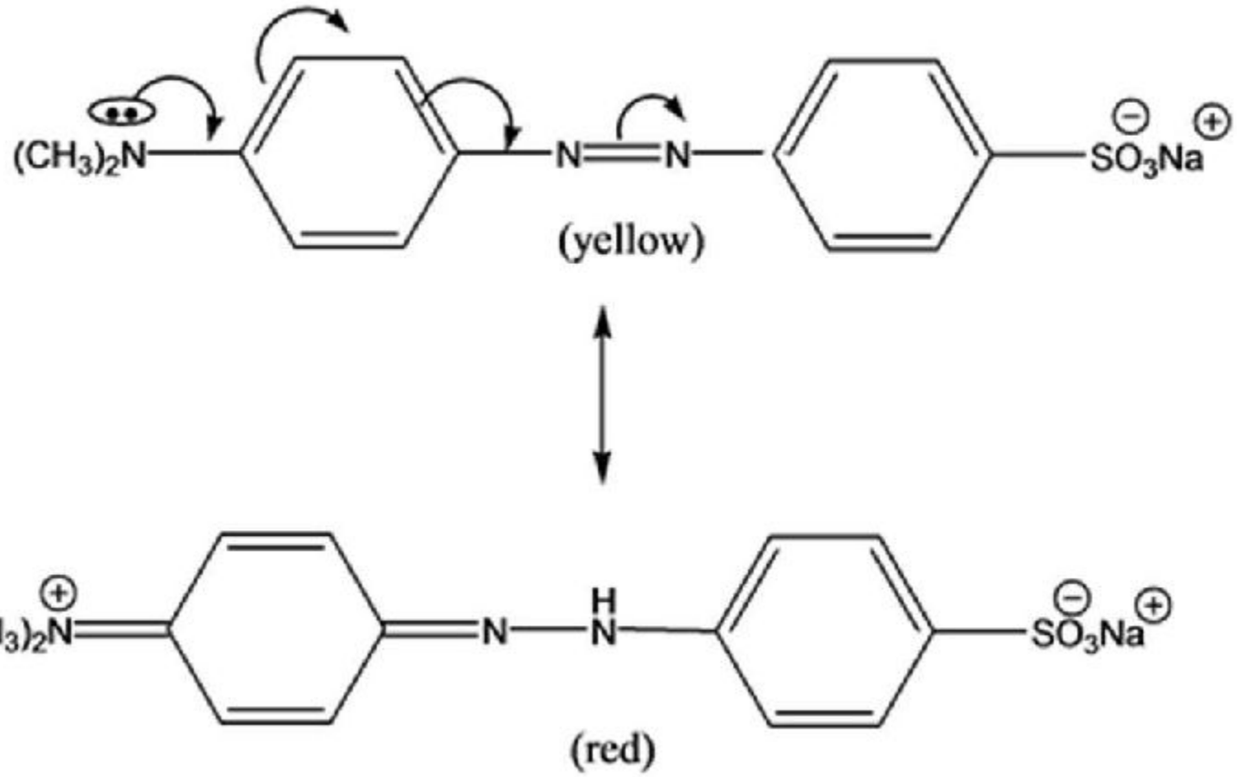
When pH changes, equilibrium shifts → color changes

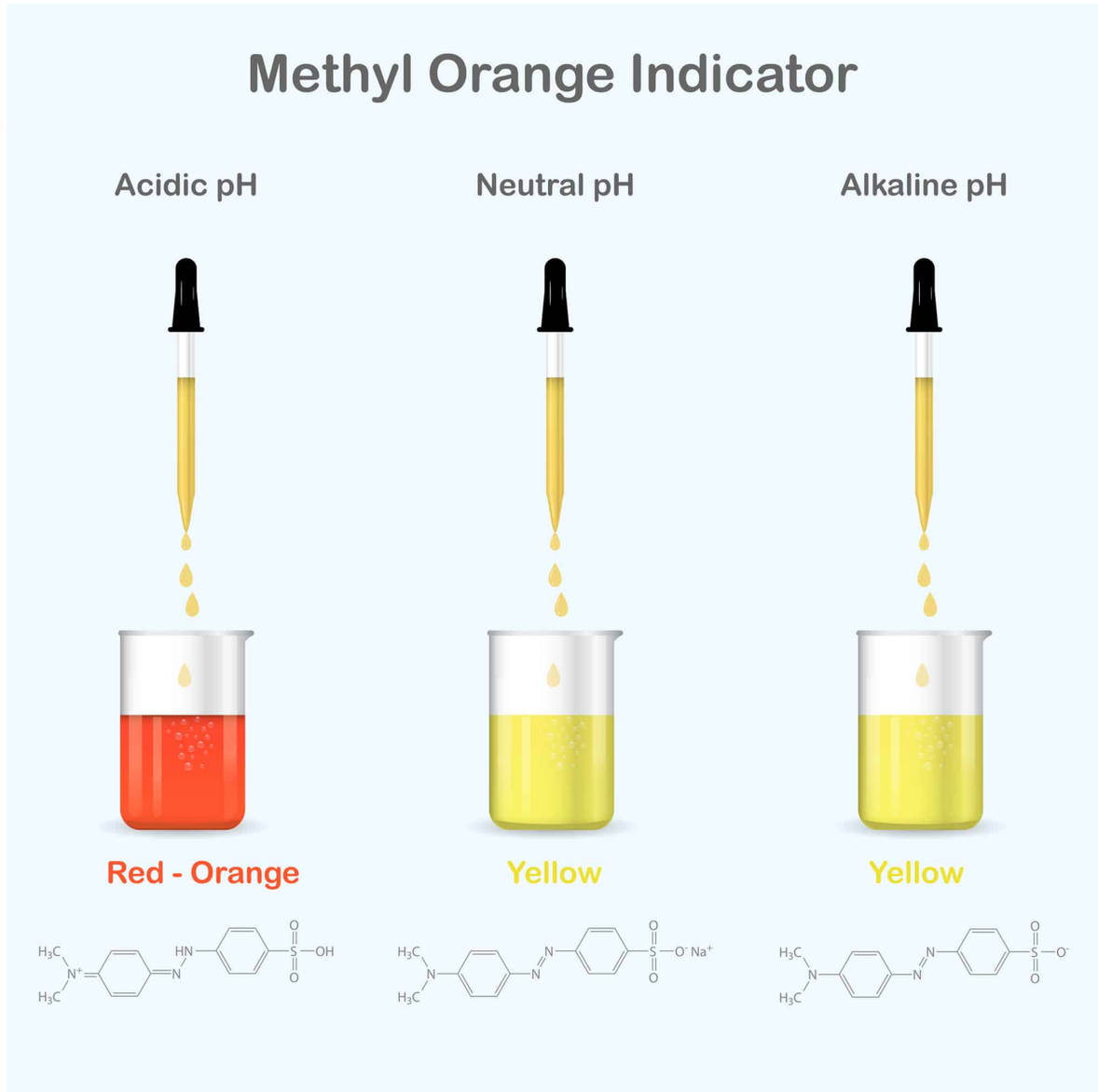
Acid–Base Indicators

Example Indicator: **Methyl Orange**

Methyl orange is an acid–base indicator commonly used in acidic systems.

- Red-Orange in acidic solution
- Yellow in basic solution
- Transition range: pH 3.1 – 4.4


(CH3)2N
N=N
SO3Na
(yellow)
(CH3)2N
N
H
N
SO3Na
(red)


Methyl Orange Indicator
Acidic pH
Neutral pH
Alkaline pH
Red - Orange
Yellow
Yellow

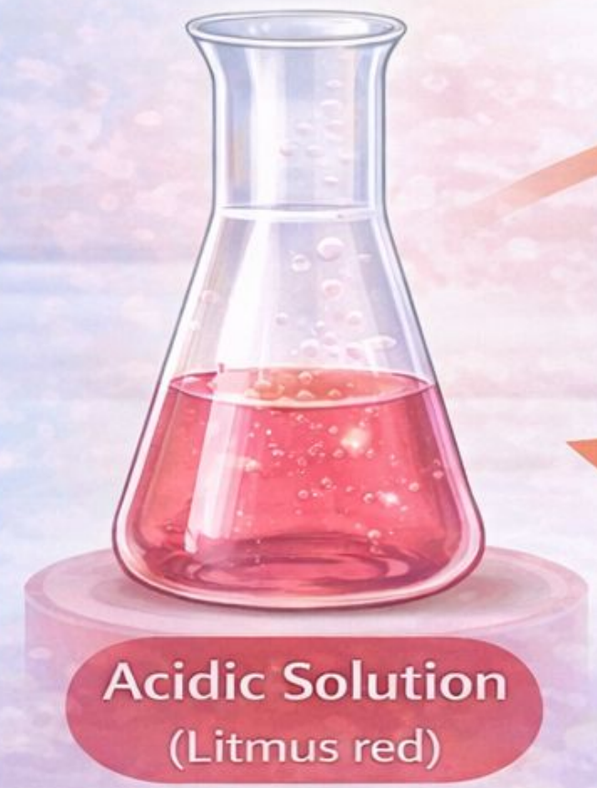
Mechanism of Acid-Base Indicators

Acidic Solution (Litmus)

After Equivalence Point

$$HIn \rightleftharpoons In^{1} + H^{+}$$

$$HIn \rightleftharpoons In^{-} + H^{+}$$



Acidic Solution
(Litmus red)

Basic Solution
(Litmus blue)

H^{+} Donor (Afci+7)

pH

H^{+} Acceptor (Base)

At low pH (acidic solution), the indicator is in its HIn form (color 1). At high pH (basic solution), the indicator is in its In^{-} form (color 2).

Acid–Base Titrations

Acid–Base Indicators

Example Indicator: Phenolphthalein

Phenolphthalein is one of the most widely used indicators.

- **Colorless in acidic and neutral solutions**
- **Pink in basic solutions**
- **Transition range: pH 8.2 – 10.0**

It is suitable for strong acid–strong base and weak acid–strong base titrations

Acid–Base Titr
Acid–Base Ind

Name	Acid Colour	pH range of colour change	Base Colour
Methyl violet	Yellow	0.0 - 1.6	Blue
Thymol blue	Red	1.2 - 2.8	Yellow
Methyl orange	Red	3.2 - 4.4	Yellow
Bromocresol green	Yellow	3.8 - 5.4	Blue
Methyl red	Red	4.8 - 6.0	Yellow
Litmus	Red	5.0 - 8.0	Blue
Bromothymol blue	Yellow	6.0 - 7.6	Blue
Thymol blue	Yellow	8.0 - 9.6	Blue
Phenolphthalein	Colourless	8.2 - 10.0	Pink
Thymolphthalein	Colourless	9.4 - 10.6	Blue
Alizarin yellow R	Yellow	10.1 - 12.0	Red

Acid–Base Titrations

Example 1

Strong acid – Strong base

HCl vs NaOH

Indicator: PhenolphthaleinReason:

Reason: Sharp pH change near equivalence point (≈7), phenolphthalein gives a clear end point.

Example 2

Strong acid – Weak base

HCl vs NH_3

Indicator: Methyl Orange

Reason: Equivalence point occurs in acidic medium (pH < 7),

Acid–Base Titrations

Practical Experiment:

Example 3

Weak acid – Strong base

CH_3COOH vs NaOH

Indicator: Phenolphthalein

Reason: Equivalence point occurs in basic medium (pH > 7), suitable for phenolphthalein.

Example 4

Strong acid – Carbonate base

HCl vs Na_2CO_3

Indicator: Methyl Orange

Reason: Complete neutralization occurs in acidic medium; methyl orange indicates the final end point