PHARM.D • YEAR 1

Pharmaceutical Inorganic Chemistry

CHAPTER 8

Theory of Indicators

PPT CHAPTER COVER



DOCTOR OF PHARMACY

Indicators: Purpose and Main Types

1 Purpose of Indicators

- Change color at (or near) the equivalence point to signal completion of the titration.
- Used in volumetric analysis (acid–base, redox, complexometric, precipitation), assay, standardization and quality control.

2 Main Types of Indicators

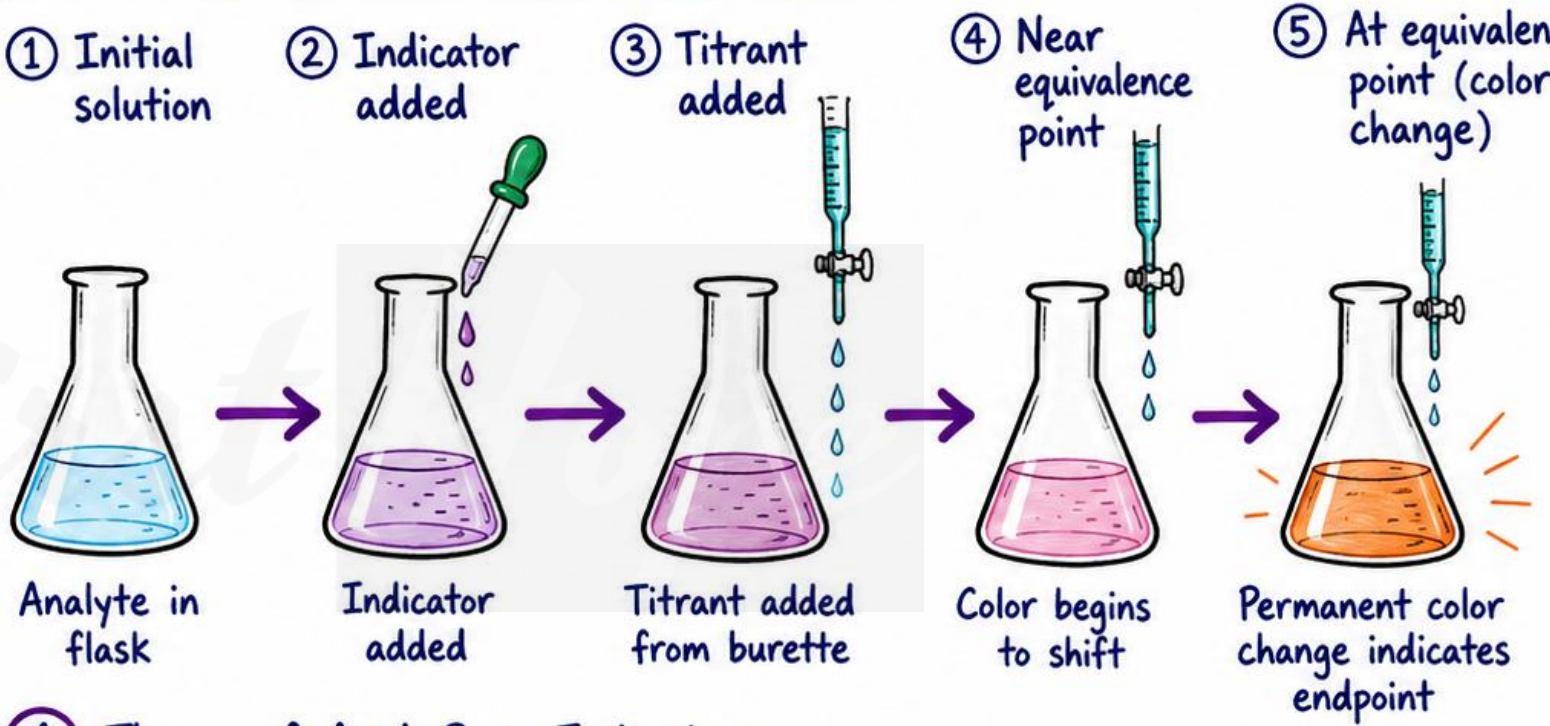
→ Acid–Base: pH indicators
Examples: Phenolphthalein, Methyl orange

→ Redox: Redox indicators
Examples: Starch, Diphenylamine

→ Complexometric: Metal ion indicators
Examples: Eriochrome Black T, Murexide

→ Precipitation: Adsorption indicators
Examples: Eosin, Fluorescein

3 How Indicators Work in a Titration



4 Theory of Acid–Base Indicators

Indicators are weak acids or weak bases that exist in two forms with different colors depending on pH.

$$HIn\,(aq) \rightleftharpoons In^-\,(aq) + H^+\,(aq)$$

(acid form) Color 1 — (base form) Color 2

pH at which indicator changes color: →

$$pH = pK_a + \log\left(\frac{[In^-]}{[HIn]}\right)$$

Acid–Base Indicator Equilibrium

1) What is an Acid–Base Indicator?

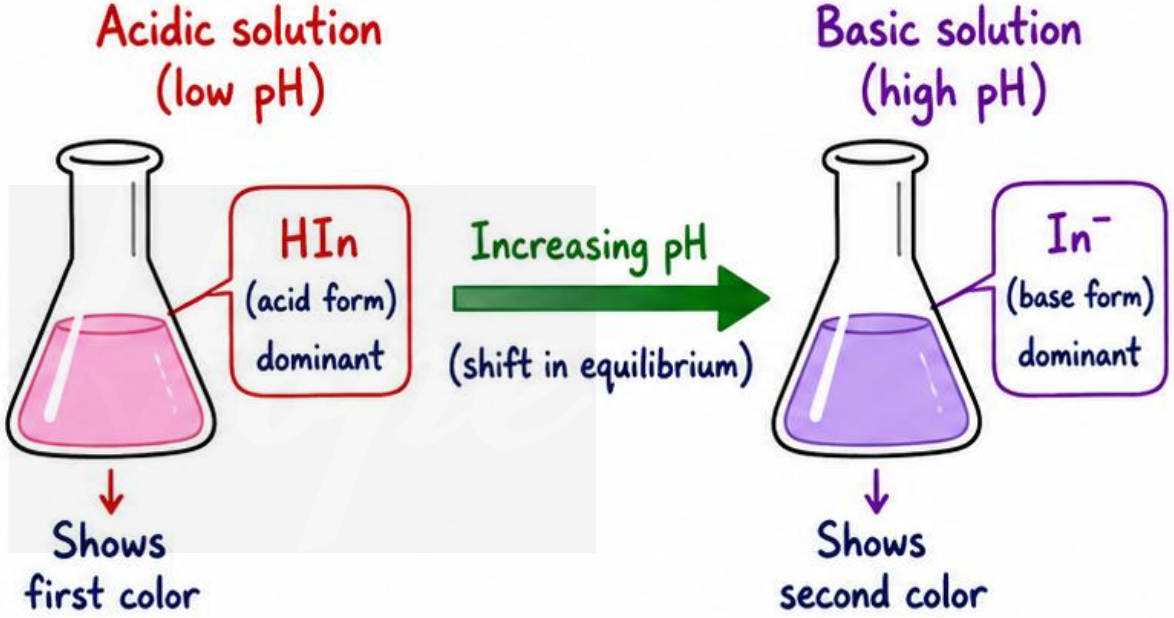
- An acid–base indicator is a weak acid or weak base that changes color with pH.
- It exists in two forms:
  - HIn (acid form) – shows one color
  - In^- (conjugate base) – shows a different color
- The color change occurs because the relative concentration of HIn and In^- changes with pH.

Equilibrium (mechanism):

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

HIn		H^+	+	In^-
acid form (one color)		hydrogen ion		conjugate base (different color)

2) Color Change & pH Relationship



3) pH at Color Change (Calculation)

To determine the pH at which an indicator changes color:

$$pH = pK_a + \log\left\{\frac{[In^-]}{[HIn]}\right\}$$

Transition Range and Henderson–Hasselbalch Idea

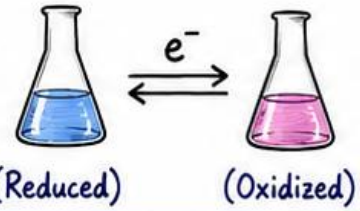
- Indicators change color over a specific pH range, usually ±1 of its pKa.
- Choose an indicator whose transition range includes the equivalence point pH for a sharp and accurate endpoint.

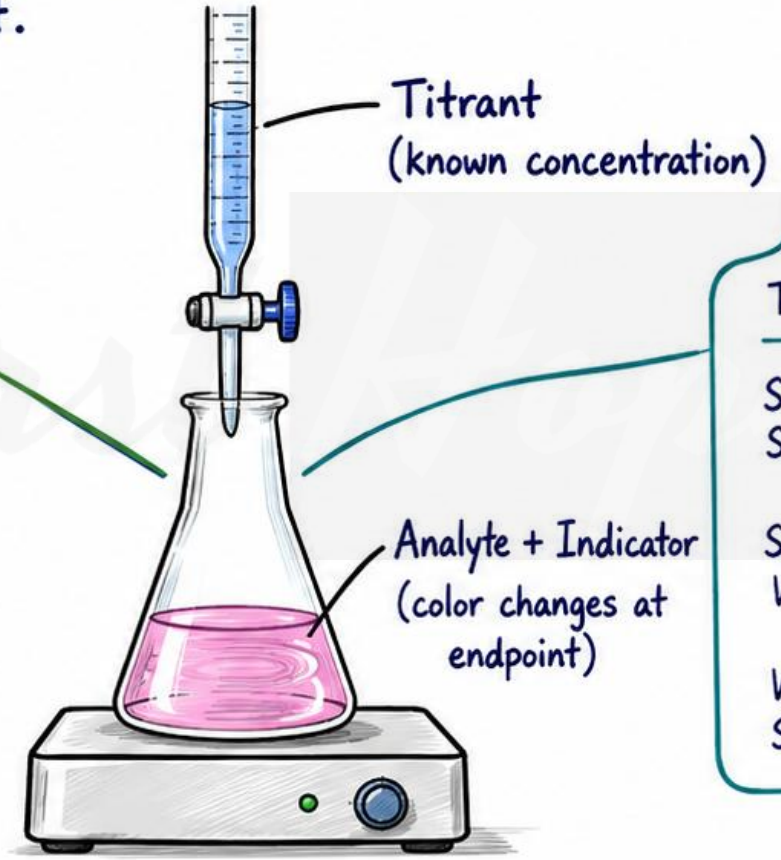
Indicator Transition Range

Indicator	pH Range	Color Change
Methyl orange	3.1 – 4.4	Red (acid) → Yellow (base)
Phenolphthalein	8.2 – 10.0	Colorless (acid) → Pink (base)

Redox Indicators

These indicators change color when they are oxidized or reduced during redox reactions.





Indicator Selection by Titration Type

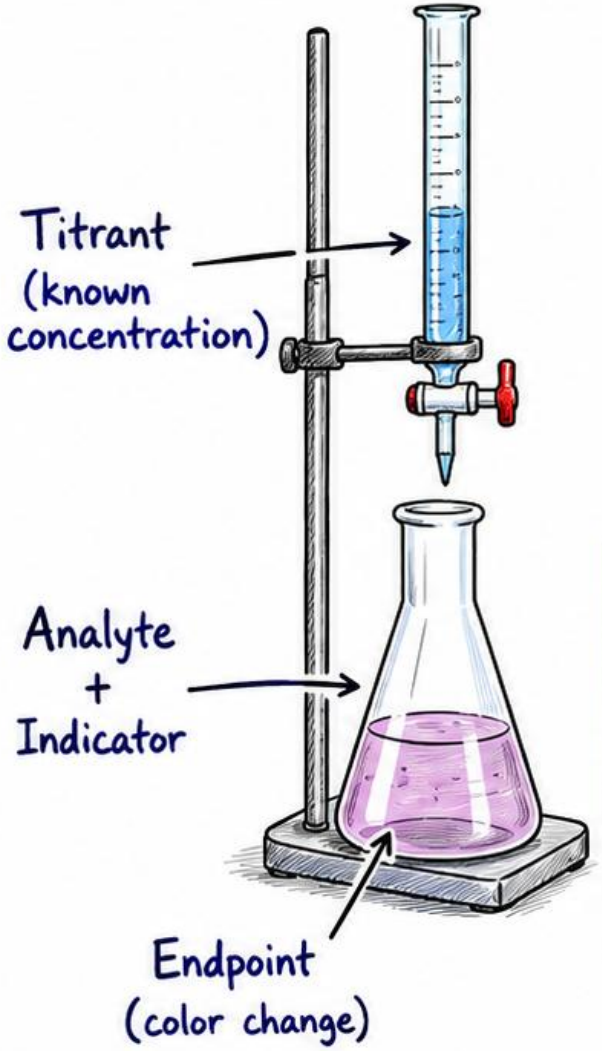
Titration Type	Equivalence Point (pH)	Suitable Indicator
Strong acid + Strong base	~ 7	Phenolphthalein or Methyl orange
Strong acid + Weak base	< 7	Methyl orange
Weak acid + Strong base	> 7	Phenolphthalein

Henderson–Hasselbalch Idea

$$pH = pK_a + \log \frac{[In^-]}{[HIn]}$$

At $pH = pK_a \rightarrow [In^-] = [HIn]$ (midpoint of transition; mix of both colors)

Selecting an Acid-Base Indicator



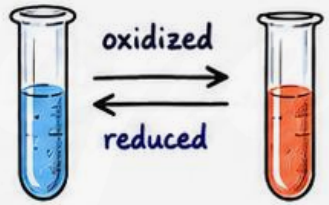
At pH < pKa, more HIn is present – acid color dominates.

Indicator Range: Every indicator changes color over a specific pH range, usually ±1 of its pKa.

Indicator	pH Range	Color Change
Methyl orange	3.1 – 4.4	Red (acid) → Yellow (base)
Phenolphthalein	8.2 – 10.0	Colorless (acid) → Pink (base)

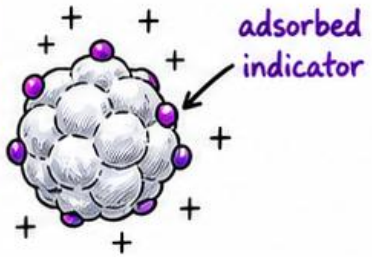
The choice of indicator depends on the type of titration and the pH at the equivalence point.

Titration Type	Equivalence Point (pH) Suitable Indicator
Strong acid + Strong base	~ 7 Phenolphthalein or Methyl orange
Strong acid + Weak base	< 7 Methyl orange
Weak acid + Strong base	> 7 Phenolphthalein



① Redox Indicators

These indicators change color when they are oxidized or reduced during redox reactions.



② Adsorption Indicators

Used mainly in precipitation titrations, such as argentometric titrations involving silver nitrate.

Mechanism: The indicator is adsorbed onto the surface of the precipitate. At the equivalence point, a change in surface charge occurs, which alters the color of the adsorbed indicator.

☆ **TAKEAWAY:** Select an indicator whose color change range overlaps the pH at the equivalence point to achieve a sharp and accurate endpoint in the titration.

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