TITRATION

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Types of titrations:

There are many types of titrations with different procedures and goals. The most common types of quantitative titration are **acid base titrations** and **redox titrations.**

1. Acid base titrations

- Acid-base titrations depend on the neutralization between an acid and a base when mixed in solution. In addition to the sample, an appropriate indicator is added to the titration chamber, reflecting the pH range of the equivalence point. The acid-base indicator indicates the endpoint of the titration by changing color.

The following table show some indicators used with their pH ranges and colors of each :

Indicator	Color on acidic side	Range of pH color change	Color on basic side
Methyl Violet	Yellow	0.0–1.6	Violet
Bromophenol Blue	Yellow	3.0–4.6	Blue
Methyl Orange	Red	3.1–4.4	Yellow
Methyl Red	Red	4.4–6.3	Yellow
Litmus	Red	5.0–8.0	Blue
Bromothymol Blue	Yellow	6.0–7.6	Blue
Phenolphthalein	Colorless	8.3–10.0	Pink
Alizarin Yellow	Yellow	10.1–12.0	Red

- The endpoint and the equivalence point are not exactly the same because the equivalence point is determined by the stoichiometry of the reaction while the endpoint is just the color change from the indicator. Thus, a careful selection of the indicator will reduce the indicator error.

- For example, if the equivalence point is at a pH of 8.4, then the Phenolphthalein indicator would be used instead of Alizarin Yellow because phenolphthalein would reduce the indicator error
- When more precise results are required, or when the reagents are a weak acid and a weak base, a pH meter or a conductance meter are used.

2. Redox titration

- Redox titrations are based on a reduction-oxidation reaction between an oxidizing agent and a reducing agent. A potentiometer or a redox indicator is usually used to determine the endpoint of the titration, as when one of the constituents is the oxidizing agent potassium dichromate, the color change of the solution from orange to green is not exact, therefore an indicator such as sodium diphenylamine is used.

- Some redox titrations do not require an indicator, due to the intense color of the constituents. For example, in permanganometry a slight faint persisting pink color signals the endpoint of the titration because of the color of the excess oxidizing agent potassium permanganate.[10]

3.Gas phase titration

Gas phase titrations are titrations done in the gas phase, specifically as methods for determining reactive species by reaction with an excess of some other gas, acting as the titrant. In one common the gas phase titration, gaseous ozone is titrated with nitrogen oxide according to the reaction:

$$O_3 + NO \rightarrow O_2 + NO_2.$$ [11][12]

- After the reaction is complete, the remaining titrant and product are quantified (e.g., by FT-IR); this is used to determine the amount of analyte in the original sample.

4. Complexometric titration

Complexometric titrations rely on the formation of a complex between the analyte and the titrant. In general, they require specialized indicators that form weak complexes with the analyte.

Common examples are Eriochrome Black T for the titration of calcium and magnesium ions, and the chelating agent EDTA used to titrate metal ions in solution.[13]

5. Back titration

- Back titration is a titration done in reverse; instead of titrating the original sample, a known excess of standard reagent is added to the solution, and the excess is titrated. A back titration is useful if the endpoint of the reverse titration is easier to identify than the endpoint of the normal titration, as with precipitation reactions.

- Back titrations are also useful if the reaction between the analyte and the titrant is very slow, or when the analyte is in a non-soluble solid.[16]

Measuring the endpoint of a titration

- There are different methods to determine the endpoint include:[17]

1. **Indicator**: A substance that changes color in response to a chemical change. An acid-base indicator (e.g., phenolphthalein) changes color depending on the pH. Redox indicators are also used. A drop of indicator solution is added to the titration at the beginning; the endpoint has been reached when the color changes.

2. Potentiometer: An instrument that measures the electrode potential of the solution. These are used for redox titrations; the potential of the working electrode will suddenly change as the endpoint is reached.

The pH meter is a potentiometer with an electrode whose potential depends on the amount of H^+ ion present in the solution. (This is an example of an ion-selective electrode.)

3. Conductivity: A measurement of ions in a solution. Ion concentration can change significantly in a titration, which changes the conductivity. (For instance, during an acid-base titration, the H^+ and OH^- ions react to form neutral H_2O.) As total conductance depends on all ions present in the solution and not all ions contribute equally (due to mobility and ionic strength).

4. **Color change:** In some reactions, the solution changes color without any added indicator. This is often seen in redox titrations when the different oxidation states of the product and reactant produce different colors.
5. **Spectroscopy:** Used to measure the absorption of light by the solution during titration if the spectrum of the reactant, titrant or product is known. The concentration of the material can be determined by Beer's Law.

6. Precipitation: If a reaction produces a solid, a precipitate will form during the titration. A classic example is the reaction between Ag^+ and Cl^- to form the insoluble salt AgCl. Cloudy precipitates usually make it difficult to determine the endpoint precisely. To compensate, precipitation titrations often have to be done as "back" titrations .

7. Amperometry: Measures the current produced by the titration reaction as a result of the oxidation or reduction of the analyte. The endpoint is detected as a change in the current. This method is most useful when the excess titrant can be reduced, as in the titration of halides with Ag^{+}.

8. Isothermal titration calorimeter :

An instrument that measures the heat produced or consumed by the reaction to determine the endpoint. Used in biochemical titrations, such as the determination of how substrates bind to enzymes.

9. Thermometric titrimetry:

Differentiated from calorimetric titrimetry because the heat of the reaction (as indicatedby temperature rise or fall) is not used to determine the amount of analyte in the sample solution. Instead, the endpoint is determined by *the rate of temperature change*.