

BT514 – ANALYTICAL CHEMISTRY

FINAL TERM MOST IMPORTANT QUESTIONS

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GROUP LINK: <https://chat.whatsapp.com/BjC6W0jZx8o9yaC2lSh1Gu>

1. What are complementary colors?

In analytical chemistry, complementary colors refer to pairs of colors that, when combined, produce a neutral color (typically white or grey). This concept is particularly important in colorimetric and spectrophotometric analyses, where the color of a solution can be used to infer the concentration of a substance.

Explanation:

- When a compound absorbs light of a particular wavelength (color), the color observed is the complementary color of the absorbed light.
- For example, if a substance absorbs light in the blue region (~450 nm), the solution may appear orange, which is the complementary color of blue.

Application in Analytical Chemistry:

- **Colorimetry:** The intensity of the color observed (which is the complementary color of the absorbed wavelength) can be used to quantify the concentration of an analyte.
- **Spectrophotometry:** The choice of wavelength for analysis is often based on the maximum absorbance ($\lambda_{\max}$) of the analyte, and the solution will appear the complementary color of that wavelength.

2. Write functions of HCl?

Functions of HCl in Analytical Chemistry:

1. pH Control and Acidification:

- HCl is used to adjust the pH of a solution, often to make it acidic.
- Acidic conditions are necessary for certain precipitation reactions or to ensure solubility of specific ions.

2. Precipitation Reactions:

- HCl helps in the selective precipitation of metal ions.
- Example: In qualitative analysis, group II cations (e.g., Pb^{2+} , Cu^{2+}) are precipitated as sulfides in acidic medium (using HCl).

3. Preventing Hydrolysis:

- Some metal ions (like Fe^{3+} , Al^{3+}) tend to hydrolyze in water, forming insoluble hydroxides.
- HCl suppresses hydrolysis by maintaining an acidic environment.

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4. Dissolution of Samples:

- HCl helps dissolve samples or residues, particularly metal oxides and carbonates.
- For example, it reacts with carbonates to release CO_2 and form soluble chlorides.

5. Formation of Soluble Chlorides:

- HCl reacts with metal compounds to form soluble metal chlorides, which are useful in further analysis.

6. Leaching Agent:

- In metallurgy or ore analysis, HCl is used to leach metals from their ores for quantitative analysis.

7. Cleaning and Degreasing:

- Concentrated HCl is used to clean glassware or remove metal oxides from surfaces to avoid contamination in experiments.

8. Reagent in Titrations:

- Standard HCl solution is often used in acid-base titrations to determine the concentration of bases.

3. How solvents are extracted? How acids and bases are extracted from their salts?

1. How are solvents extracted?

Solvent extraction is a technique used to separate compounds based on how well they dissolve in two different liquids that do not mix, usually water and an organic solvent like ether or chloroform. When the mixture is shaken with both liquids, the compound will move into the solvent where it dissolves better. After shaking, the two layers are allowed to separate in a container like a separatory funnel. Each layer can then be collected. This method is useful in chemistry labs to isolate a desired compound or remove unwanted impurities.

2. How are acids and bases extracted from their salts?

Acids and bases can be separated from their salts using acid-base reactions. For example, if you have a salt of an organic acid (like sodium benzoate), you can add a strong acid like hydrochloric acid to it. This converts the salt back into the free acid (benzoic acid), which doesn't dissolve well in water and can be extracted using an organic solvent. Similarly, if you have a salt of a base (like an amine hydrochloride), you can add a strong base like sodium hydroxide. This forms the free base, which is also not very soluble in water and can be extracted into an organic solvent. This process helps in purifying or separating organic acids and bases from mixtures.

4. What is UV spectroscopy?

UV spectroscopy, or ultraviolet spectroscopy, is an analytical technique used to study how a substance absorbs ultraviolet (UV) light. It helps identify and analyze compounds by measuring the absorption of UV light in the range of 200 to 400 nanometers. When UV light passes through a sample, certain wavelengths are absorbed by the electrons in the molecule, causing them to move to a higher energy level (excited state). The amount of light absorbed at each wavelength gives information about the structure and concentration of the compound. In analytical chemistry, UV spectroscopy is often used to:

- Determine the concentration of a substance (using Beer-Lambert Law).
- Identify functional groups in organic molecules.
- Monitor reaction progress or purity of samples.

5. Write note on icp/oes.

ICP-OES is a powerful analytical technique used to detect and measure the concentration of metallic and non-metallic elements in a wide variety of samples, especially in environmental, industrial, pharmaceutical, and food testing. In ICP-OES, a sample solution is introduced into a very high-temperature plasma (around 10,000 K), which is created using argon gas. The energy from the plasma excites the atoms and ions in the sample, causing them to emit light at characteristic wavelengths. Each element emits light at specific wavelengths, and the intensity of this light is measured using an optical spectrometer.

6. Define ketone and aldehydes.

Ketones are organic compounds that contain a carbonyl group ($C=O$) bonded to two carbon atoms. The general structure of a ketone is $R-CO-R'$, where R and R' are alkyl or aryl groups. A common example is acetone ($CH_3-CO-CH_3$). Ketones are usually formed by the oxidation of secondary alcohols.

Aldehydes are organic compounds that also contain a carbonyl group ($C=O$), but in this case, the carbonyl carbon is bonded to at least one hydrogen atom. The general structure of an aldehyde is $R-CHO$, where R is an alkyl or aryl group, and the $-CHO$ group is the aldehyde functional group. A common example is formaldehyde ($H-CHO$). Aldehydes are often formed by the oxidation of primary alcohols.

7. What characteristics are seen in IR spectrum?

Characteristics Seen in an IR Spectrum:

An IR (infrared) spectrum shows how a compound absorbs infrared light, which causes the vibration of bonds between atoms in a molecule. The key characteristics observed in an IR spectrum include:

1. Absorption Peaks (Bands):

These are the dips or valleys in the spectrum and indicate where the molecule absorbs IR radiation. Each peak corresponds to a specific vibrational mode (like stretching or bending) of a particular bond.

2. Wavenumber (cm^{-1}):

The x-axis of an IR spectrum is in wavenumbers, typically ranging from 4000 to 400 cm^{-1} . Different functional groups absorb in specific wavenumber ranges. For example:

- **O–H** stretch (alcohols or acids): $\sim 3200-3600\text{ cm}^{-1}$
- **C=O** stretch (carbonyls): $\sim 1650-1750\text{ cm}^{-1}$
- **C–H** stretch: $\sim 2800-3100\text{ cm}^{-1}$

3. Intensity of Peaks:

The height or depth of each absorption band indicates how strongly a bond absorbs IR light. Stronger bonds or more polar bonds usually show more intense peaks.

4. Shape of Peaks:

The shape of a peak can help identify the type of bond:

- Broad peaks (e.g., O–H in alcohols)
- Sharp peaks (e.g., C=O in ketones or aldehydes)

5. Functional Group Region ($4000-1500\text{ cm}^{-1}$):

This part of the spectrum helps identify functional groups like $-OH$, $-NH$, $-CH$, $C=O$, etc.

6. Fingerprint Region ($1500\text{--}400\text{ cm}^{-1}$):

This region is unique for every molecule and is used to confirm the identity of a compound. It contains many complex vibrations and is often used to compare with known spectra.

8. Define Hollow Cathode lamp?

Hollow Cathode Lamp (HCL):

A Hollow Cathode Lamp (HCL) is a type of light source used in Atomic Absorption Spectroscopy (AAS) to provide element-specific radiation. It consists of a hollow metal cathode made of the element to be analyzed, an anode, and is filled with an inert gas like argon or neon. When a voltage is applied, the gas becomes ionized, and these ions strike the cathode, causing atoms of the cathode material to be excited. As these excited atoms return to their ground state, they emit light at characteristic wavelengths specific to that element.

Key Features:

- Produces sharp and intense spectral lines of the target element.
- Used to detect and quantify metals like sodium, calcium, iron, lead, etc.
- Provides high sensitivity and selectivity in atomic absorption measurements.

9. Explain role of stationary phase in chromatography.

Role of Stationary Phase in Chromatography

In chromatography, the stationary phase is the solid or liquid material that stays fixed inside the column or on the surface of a plate. It plays a crucial role in separating the components of a mixture. When a mixture passes through the stationary phase along with a moving phase (called the mobile phase), the different components interact differently with the stationary phase. Some components stick to the stationary phase more strongly, while others pass through quickly. Because of these varying interactions, the components separate from each other as they move along. The effectiveness of the separation depends largely on the nature of the stationary phase, such as its chemical composition and surface properties. For example, in paper chromatography, the stationary phase is water trapped in the fibers of the paper, while in column chromatography, it might be silica gel or alumina.

10. What is gravimetric analysis?

Gravimetric analysis is a quantitative analytical method in chemistry where the amount of an analyte (the substance being measured) is determined by measuring its mass. In this technique, the analyte is converted into a pure, stable, and insoluble compound (usually a precipitate). This precipitate is then carefully filtered, washed, dried or ignited, and weighed. From the mass of this solid, the amount of the original substance in the sample can be calculated using stoichiometry.

11. Describe one mechanism in which stationary phase retards movement of molecules?

Mechanism by Which the Stationary Phase Retards Movement of Molecules: Adsorption

One common mechanism through which the stationary phase slows down or retards the movement of molecules in chromatography is adsorption.

How Adsorption Works:

- The stationary phase has a surface that can attract and hold molecules from the mixture passing through.
- Molecules in the mobile phase stick (adsorb) temporarily to the surface of the stationary phase because of forces like van der Waals forces, hydrogen bonding, or dipole interactions.
- Molecules that have a stronger affinity for the stationary phase spend more time attached to it and move more slowly through the system.
- Molecules with weaker interactions stay mostly in the mobile phase and move faster.

12. Differentiate between filtration and sublimation.

Filtration is a physical method used to separate an insoluble solid from a liquid or gas by passing the mixture through a filter, such as filter paper. The solid particles are trapped on the filter, while the liquid or gas passes through. This method is commonly used when the solid does not dissolve in the liquid, like separating sand from water.

Sublimation is a process where a solid changes directly into a gas without first becoming a liquid. It is used to purify substances that can sublime, such as iodine or dry ice. When heated, the solid turns into vapor and then re-solidifies upon cooling, leaving behind impurities. Unlike filtration, sublimation involves a change in the physical state of the substance.

13. What is scatter diagram?

A scatter diagram (or scatter plot) is a graphical tool used to show the relationship between two variables. It consists of points plotted on a coordinate system, where each point represents paired values of the two variables being studied. In analytical chemistry and other sciences, scatter diagrams help visualize whether there is a correlation or pattern between the variables—such as a positive, negative, or no correlation. For example, it can show how the concentration of a substance changes with temperature or time.

14. Write note on solid phase extraction.

Solid Phase Extraction (SPE) is a sample preparation technique widely used in analytical chemistry to separate, concentrate, and purify compounds from liquid mixtures. It involves passing a liquid sample through a cartridge or column filled with a solid adsorbent material (the stationary phase). The target compounds in the sample adsorb onto the solid phase, while impurities are washed away. Later, the compounds of interest are eluted (washed out) using a suitable solvent. SPE is especially useful for isolating trace amounts of substances from complex samples like blood, water, or food.

Advantages of SPE:

- Efficient concentration of analytes.
- Removal of interfering substances.
- Faster and cleaner than traditional liquid-liquid extraction.
- Uses less solvent, making it environmentally friendly.

15. Why transition metals show color in organic compound?

Transition metals show color in their compounds because of the way their d-electrons interact with light. These metals have partially filled d-orbitals, and when they form complexes with organic molecules (called ligands), the energy levels of these d-orbitals split into different groups. When visible light passes through or reflects from these compounds, some wavelengths of light are absorbed to promote electrons from lower-energy d-orbitals to higher-energy d-orbitals (a process called d–d electronic transition). The color we see is the combination of the wavelengths of light not absorbed, which are transmitted or reflected. The exact color depends on factors such as:

- The metal ion itself.
- The nature of the ligands attached.
- The geometry of the complex.

16. Explain classical analytical methods.

Classical Analytical Methods

Classical analytical methods refer to traditional techniques used in chemistry to determine the composition and concentration of substances without using modern instrumental tools. These methods rely mostly on chemical reactions, physical changes, and simple measurements. There are two main types:

1. **Gravimetric Analysis:** This method involves measuring the mass of an analyte or its derivative. The substance is converted into a pure, insoluble compound, which is then filtered, dried, and weighed. From the mass of this solid, the amount of the original substance can be calculated. Gravimetric analysis is known for its accuracy and precision.
2. **Volumetric Analysis (Titrimetry):** This involves measuring the volume of a solution of known concentration (titrant) required to completely react with the analyte. Common titrations include acid-base, redox, precipitation, and complexometric titrations. The endpoint is usually detected by a color change using indicators or by using instruments.

17. What is trident? What is its role in titration?

Trident is a common name for Trisodium triethylenetetraminehexaacetate, a chelating agent used in complexometric titrations. It belongs to a group of ligands that can bind metal ions strongly by forming stable complexes.

Role of Trident in Titration

In titration, particularly complexometric titration, Trident acts as a chelating agent that binds with metal ions in the solution. It helps to:

- Form a stable complex with metal ions, preventing precipitation.
- Improve the accuracy and sharpness of the titration endpoint.
- Sometimes be used as an indicator or assist indicators by stabilizing the metal ion in solution.

18. Explain dissociation of weak acid and base.

Dissociation of Weak Acids and Bases

Weak acids and bases do not completely ionize or dissociate in water. Instead, they exist in a balance between their undissociated (molecular) form and their ionized form.

Dissociation of a Weak Acid:

A weak acid (HA) partially ionizes in water. Only a small fraction of the acid molecules release hydrogen ions (H^+), while most remain as undissociated acid molecules. Because of this partial dissociation, weak acids have an equilibrium constant (K_a) that is much less than 1.

Dissociation of a Weak Base:

A weak base (B) partially accepts protons in water. Here, only some of the base molecules react with water to form hydroxide ions (OH^-) and their conjugate acid (BH^+). The extent of this reaction is described by the base dissociation constant (K_b).

19. What is potentiometric titration?

Potentiometric titration is a type of titration where the progress of the reaction is monitored by measuring the electrical potential (voltage) of the solution instead of using a color indicator. In this method, an electrode (often a glass electrode or an ion-selective electrode) is immersed in the solution, and the change in potential is recorded as a titrant is gradually added. The potential changes because the concentration of certain ions in the solution changes during the titration. The endpoint of the titration is determined by observing a sudden change or inflection in the measured potential, which corresponds to the completion of the reaction.

Advantages:

- Useful when there is no suitable indicator.
- Can be used for colored or turbid solutions where visual indicators are hard to see.
- More precise and accurate for some types of titrations, such as acid-base, redox, and complexometric titrations.

20. Define Ligand and its role.

A ligand is an atom, ion, or molecule that can donate one or more pairs of electrons to a central metal atom or ion to form a coordination complex. Ligands bind to the metal through these electron pairs, creating coordinate covalent bonds.

Role of Ligands:

- Ligands stabilize metal ions by surrounding them and forming complexes.
- They influence the chemical properties of the metal center, such as its reactivity, color, and magnetic behavior.
- In analytical chemistry, ligands are used in complexometric titrations to selectively bind metal ions, allowing their quantitative determination.
- Ligands help in solubilizing metals, making them easier to analyze or separate.

21. Define IR spectral factors of aldehyde and ketones.

In infrared (IR) spectroscopy, aldehydes and ketones show characteristic absorption bands mainly due to their carbonyl (C=O) group. Here are the key IR spectral features:

Aldehydes:

- **C=O Stretch:** A strong, sharp absorption band appears around $1720\text{--}1740\text{ cm}^{-1}$ due to the carbonyl group.
- **C–H Stretch (Aldehyde Hydrogen):** Two distinctive weak to moderate bands appear around $2720\text{--}2820\text{ cm}^{-1}$, known as the aldehyde C–H stretch. These are usually absent in ketones.
- **Other Bands:** C–H stretches from the alkyl groups appear around $2850\text{--}2960\text{ cm}^{-1}$.

Ketones:

- **C=O Stretch:** A strong, sharp absorption band typically appears around $1705\text{--}1725\text{ cm}^{-1}$.
- **Absence of Aldehyde C–H Stretch:** Unlike aldehydes, ketones do not show the characteristic aldehyde C–H stretch near $2700\text{--}2800\text{ cm}^{-1}$.
- **Alkyl C–H Stretches:** Similar to aldehydes, alkyl C–H stretching bands appear around $2850\text{--}2960\text{ cm}^{-1}$.

22. What is histogram?

A histogram is a type of bar graph that represents the distribution of numerical data. It shows how frequently different ranges or intervals (called bins) of data occur in a dataset. Histograms are useful for visualizing the shape, spread, and central tendency of data, helping to identify patterns like skewness, peaks, or outliers. In a histogram:

- The x-axis represents the intervals or classes of the data.
- The y-axis shows the frequency or number of data points within each interval.
- The bars are drawn adjacent to each other (without gaps) to indicate continuous data.

23. What is change of electrons with respect to acidity, basicity proportional to the wavelength of molecules.

Relationship Between Electron Changes, Acidity/Basicity, and Wavelength

The acidity or basicity of a molecule depends on its ability to donate or accept electrons or protons, which affects the electronic structure of the molecule. When a molecule undergoes changes in electron distribution—such as losing a proton (acidic behavior) or gaining one (basic behavior)—its energy levels change. These changes influence the way the molecule absorbs light.

- Electronic transitions (like in UV-Vis spectroscopy) occur when electrons move between energy levels.
- The energy difference (ΔE) between these levels determines the wavelength (λ) of light absorbed.

So, when electron density shifts due to acidity/basicity changes, it can alter ΔE , thus changing the wavelength at which the molecule absorbs light. For example, protonation (adding H^+) or deprotonation (removing H^+) can shift the absorption maxima, which is often observed as a change in color or absorption peak in spectroscopic studies.

Disclaimer:

For best results, it is advised NOT to rely on this file only. Go through video lectures, handouts and other sources as well.

Regards,

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