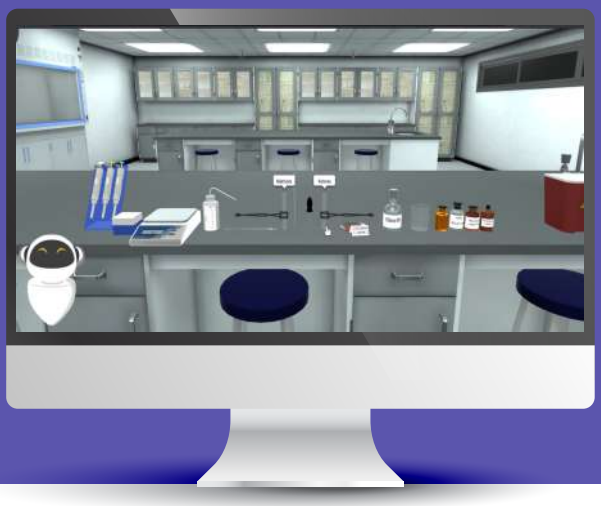
Chemistry | Organic Chemistry

Tests for Aldehydic and Ketonic Groups



General Aim

Identification and Differentiation between Aldehydes and Ketones through the chemical detection of aldehyde and ketone carbonyl groups, respectively.

Method

Detection of the presence of aldehydes and ketones using special and specific reagents.

Learning Objectives (ILOs)

- Define and differentiate between carbonyl groups of aldehydes and ketones theoretically through their chemical structure.
- Classify organic compounds containing carbonyl groups into aldehydes and ketones.
- Compare between aldehydes and ketones in terms of chemical structures, properties and reactions.
- Select the appropriate reagents to differentiate between aldehydes and ketones.
- Identify aldehydic and ketonic functional groups in organic compounds by performing 2,4-dinitrophenylhydrazine test.
- Differentiating between aldehydes and ketones by Tollen's, Schiff's Test and Fehling's Tests.

Theoretical Background/Context

- Aldehydes and ketones are two classes of organic compounds that possess at least one carbonyl group (C=O). Aldehydes (R – CHO) are characterized by having a terminal CHO in their structure, while ketones (R – CO – R') are characterized by having C=O within their structures. R and R' represents the alkyl or aryl substituents on the carbon atom of the carbonyl group. In other words, the carbonyl group of an aldehyde is linked to one alkyl/aryl group and an H atom, while that of as ketone is linked to two alkyl/aryl groups.
- The role that aldehydes and ketones play in our real life is controlled by their properties. Aldehydes and ketones are used in various applications in different fields such as food industry, cosmetics, pharmaceutics, etc.

First: Common Uses of Aldehydes

- Formaldehyde, a gaseous aldehyde compound is used to prepare 40% w/v solution. This solution is known commercially as formalin and used to the preservation biological samples. Formaldehyde also reacts with phenol to form Bakelite that is used in different industries e.g. adhesives, coatings. Polymers and plastics. It also acts a fungicide or insecticide. Finally, it is used in photography.
- Acetaldehyde, another common example of acetaldehyde, is used as a raw material for preparation of some chemicals such as acetic acid and pyridine derivatives.
- Benzaldehyde, an aromatic aldehyde, is a fundamental ingredient in cosmetics, dyes and, perfumes. It is also used as a flavoring additive (almond like) in many food products. It also acts as a bee repellant.
- Many other aldehydes are responsible for specific fragrance and flavors in baking and foods such as cinnamon, vanilla and coriander. Aldehydes are also important ingredient in caramelization of sugars as they responsible for the color and taste of caramel. Finally, some aldehydes are also responsible for sweet odors in fragrance and perfume production.

Theoretical Background/Context (Cont')

Second: Common Uses of Ketones

- Generally, a lot of ketone are used as solvents in plastics and synthetic fibers industry.
- Propanone (acetone), commonly and commercially known as acetone, is used as a paint thinner and nail paint remover. It is also used in medical and pharmaceutical applications such as chemical peeling and acne treatments.
- Ethyl methyl ketone, also known as butanone, is one of the commonly used solvents in many industries such as in textiles, paints & varnishes, paraffin wax, polymers & plastic production, etc.
- Cyclohexanone, a cyclic ketone, is an important raw material in nylon industry.
- Finally, many ketones such as acetophenone have characteristic sweet odor (such as cherry, jasmine, honeysuckle, almond, strawberry, etc.), so they are included in perfume industries.
- This experiment is designed in order to confirm the presence of aldehydes and ketones in certain samples. In addition, it can differentiate between aldehydes and ketones. In other words, the experiment is designed for the qualitative analysis of aldehydes and ketones.

Principle of Work

- In this experiment, aldehydes and ketones are tested through detecting their carbonyl groups through different chemical tests. In addition, these tests can be used to differentiate between the two classes. This is done through conducting different tests using different reagents such as phenylhydrazine, Tollen's Test, Schiff's Test and Fehling's Test.

First: Phenylhydrazine Test

- In this test, 2,4-dinitrophenylhydrazine is used which reacts with carbonyl groups, forming phenylhydrazones. Phenylhydrazones are colored compounds and their color differs according the whether the sample contains an aldehyde or ketone. Specifically it gives a red color in case of aldehyde, while yellow or orange in case of ketones.

Second: Tollen's (Silver Mirror) Test

- It depends on the fact that aldehydes can be oxidized into their corresponding carboxylic acids, while ketones cannot. This test is named after the name of the used reagent, Tollens' reagent. Tollens' reagent is a colorless basic aqueous solution composed of silver ions linked to ammonia [Ag(NH3)2+]. It is prepared through two steps:

Step 1: Preparation of Silver Oxide (Ag2O)

$$AgNO_3 + NaOH \rightarrow AgOH + HNO_3$$

$$2AgOH \rightarrow Ag_2O\downarrow + H_2O$$

Step 2: Preparation of Tollen's reagent

$$Ag_2O + 4\ NH_3 + H_2O \rightarrow 2Ag(NH_3)^+_2 + 2OH^-$$

- In this test, Tollen's reagent differentiates between aldehydes and ketones since it is able to oxidize aldehydes only to their corresponding carboxylic acid. During the reaction, the silver ins are reduced to precipitate as metallic silver (Ag0) forming a mirror at the bottom of the test tube as shown in figure 1 in the left hand side tube. On the other hand, no reaction proceeds in case of ketones ending up with a negative test result as shown in Figure 1 in the right hand side tube.

Principle of Work (Cont')

Third: Schiff's Test

- Schiff's reagent is prepared through mixing concentrated hydrochloric acid, sodium bisulphite and triphenylmethane dye together. Schiff's reagent itself has no color. However, it reacts with aldehyde in the presence of sulfurous acid giving a complex with red brick color.
- Schiff's reagent (Colorless) Complex with aldehyde (Brick red Color).
- On the other hand, ketone gives a negative result in this test as it cannot form complex with the reagent.

Forth: Fehling Test

- Fehling test is used to detect reducing sugars so it is used to differentiate between aldehydes and ketones. Using Fehling test, aldehydes give positive results (reddish brown precipitate), while ketone does not.
- Fehling reagent is composed of two solutions; Fehling A and Fehling B. Fehling A is an aqueous copper sulphate solution ($CuSO_4$), while Fehling B is an alkaline aqueous solution of sodium potassium tartrate (Rochelle salt). Rochelle salt acts as a chelating agent. Fehling A and Fehling B are mixed in equal amounts prior to being used to differentiate between aldehydes and ketones. Fehling test gives a positive result with an aldehyde, while a negative result with a ketone. Upon heating the aldehyde is oxidized, its corresponding carboxylic acid, while cupric oxide (CuO) is reduced to cuprous oxide (Cu_2O) which is a reddish brown precipitate.