Introduction

Aldehydes and ketones are two important classes of organic compounds characterized by the presence of a carbonyl group (C=O).

In aldehydes, the carbonyl group is bonded to at least one hydrogen atom, while in ketones, the carbonyl group is bonded to two carbon atoms.

These compounds are widespread in nature and serve as key intermediates in many chemical and biological processes.

The carbonyl group is highly reactive due to the polarity of the C=O bond, making aldehydes and ketones useful in various synthetic pathways.

Understanding their structure, nomenclature, properties, preparation methods, and reactivity is fundamental to mastering organic chemistry.

1. Nomenclature of Aldehydes and Ketones

1.1 Aldehydes:

- The IUPAC names of aldehydes are derived from the corresponding alkane by replacing the '-e' with '-al'.

- The carbon in the carbonyl group is always assigned position 1.

- Examples: Methanal (formaldehyde), Ethanal (acetaldehyde), Butanal

1.2 Ketones:

- The IUPAC names of ketones are derived from the corresponding alkane by replacing the '-e' with '-one'.

- The position of the carbonyl group must be specified for ketones with more than three carbon atoms.

- Examples: Propanone (acetone), Butan-2-one

2. Structure and Physical Properties

- The carbonyl group is planar with bond angles approximately 120°.

- Aldehydes and ketones are polar compounds due to the C=O bond dipole.

- Boiling points are higher than alkanes but lower than alcohols due to the absence of hydrogen bonding.

- Solubility: Lower aldehydes and ketones are soluble in water; solubility decreases with increasing chain length.

Table: Comparison of Physical Properties

Property	Aldehydes	Ketones
Polarity	High	High
Boiling Point	Moderate to High	Moderate to High
Water Solubility	High (short-chain)	High (short-chain)

3. Methods of Preparation

3.1 Aldehydes:

- Oxidation of primary alcohols using PCC (Pyridinium chlorochromate).

- Partial reduction of esters or acid chlorides.

3.2 Ketones:

- Oxidation of secondary alcohols using potassium dichromate (K2Cr2O7).

- Friedel-Crafts acylation of aromatic rings.

- Hydration of alkynes (for methyl ketones).

Reactions:

$CH_3CH_2OH + [O] \rightarrow CH_3CHO + H_2O$

$CH_3CH(OH)CH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$

4. Chemical Reactions

4.1 Nucleophilic Addition:

- Aldehydes and ketones undergo nucleophilic addition due to the electrophilic nature of the carbonyl carbon.

- Examples: Addition of water (hydrate formation), alcohols (hemiacetal and acetal formation), amines (imine formation).

4.2 Oxidation:

- Aldehydes are easily oxidized to carboxylic acids.

- Ketones are resistant to oxidation under mild conditions.

4.3 Reduction:

- Aldehydes reduce to primary alcohols.

- Ketones reduce to secondary alcohols.

- Reducing agents: NaBH4, LiAlH4

4.4 Special Reactions:

- Aldol condensation: Involving enolate ions and carbonyl compounds.

- Wolff–Kishner reduction: Converts carbonyl group to methylene using hydrazine and base.

- Clemmensen reduction: Uses Zn(Hg)/HCl to reduce carbonyl groups.

5. Laboratory Tests

5.1 Tollens' Test:

- Reagent: Ammoniacal silver nitrate solution.

- Positive result (aldehydes): Formation of silver mirror.

- Negative result (ketones): No reaction.

5.2 Fehling's Test:

- Reagent: Cu2+ in alkaline solution.

- Positive result (aldehydes): Red precipitate of Cu2O.

- Negative result (ketones): No reaction.

5.3 2,4-DNP Test:

- Both aldehydes and ketones form yellow/orange precipitates with 2,4-dinitrophenylhydrazine.

6. Applications and Importance

- Aldehydes such as formaldehyde are used in resins and disinfectants.

- Ketones like acetone are common solvents in industry and laboratories.

- Many natural flavors and fragrances contain carbonyl compounds.

- Aldehydes and ketones serve as intermediates in the synthesis of drugs, dyes, and plastics.

7. Solved Problems

Problem 1:

Write the product of oxidation of 2-propanol.

Answer: CH_3COCH_3 (acetone)

Problem 2:

Differentiate between aldehyde and ketone using Tollens' reagent.

Answer: Aldehyde forms silver mirror; ketone shows no reaction.

Problem 3:

Write the product when acetone reacts with hydrazine in basic medium.

Answer: Propane (via Wolff–Kishner reduction)

8. Homework Assignment

Q1: Write the balanced chemical equation for oxidation of ethanol.

Q2: Describe the result of Fehling's test with butanone.

Q3: Explain the mechanism of acetal formation from an aldehyde.