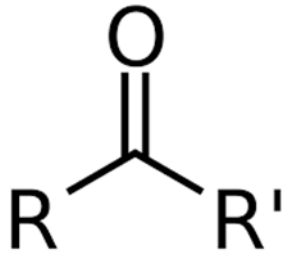
MEDICAL CHEMISTRY

Aldehydes and Ketones

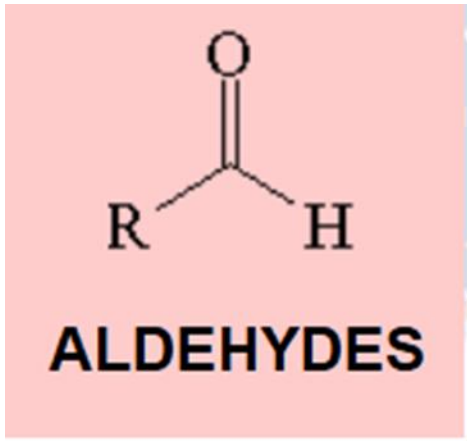


Lecture : Medical Chemistry (Lecture 9)
Stage : 1st Stage
Lecturer : Dr. Mustafa Abdul Jabbar Al-Jumaili
Department: Chemistry and Biochemistry department
Date: 22/ 1/ 2026

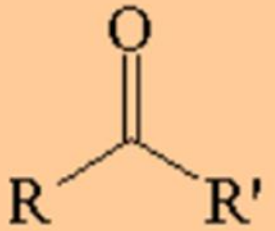
Learning Objectives

- **Structure & Nomenclature:** Distinguish between aldehydes and ketones, apply IUPAC naming rules, and explain physical properties (solubility/BP).
- **Reactions & Diagnosis:** Master key reactions (Oxidation, Reduction, Nucleophilic Addition) and identification methods (Tollens' test).
- **Biological Significance:** Understand the role of carbonyls in carbohydrates (Glucose), and clotting (Vitamin K).
- **Clinical Applications:** Relate chemical properties to metabolic conditions (Diabetic Ketoacidosis) and pharmaceuticals (Corticosteroids).

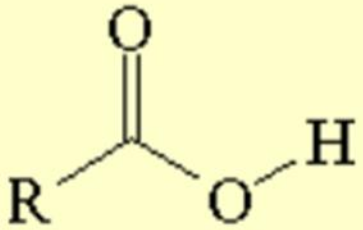
Carbonyl functional groups



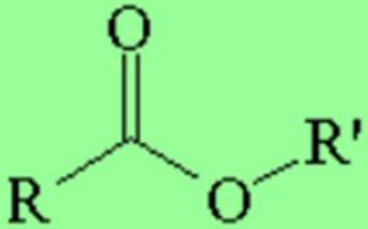
ALDEHYDES



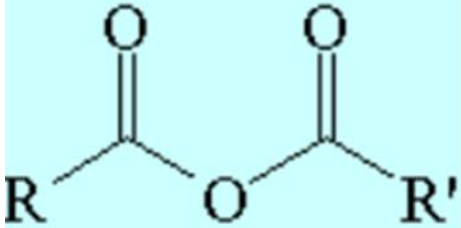
KETONES



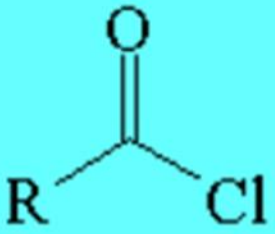
Carboxylic acids



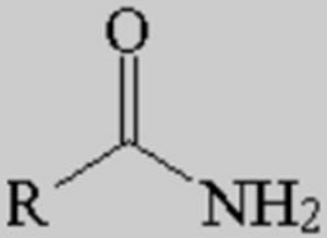
Esters



Anhydrides



Acyl halides



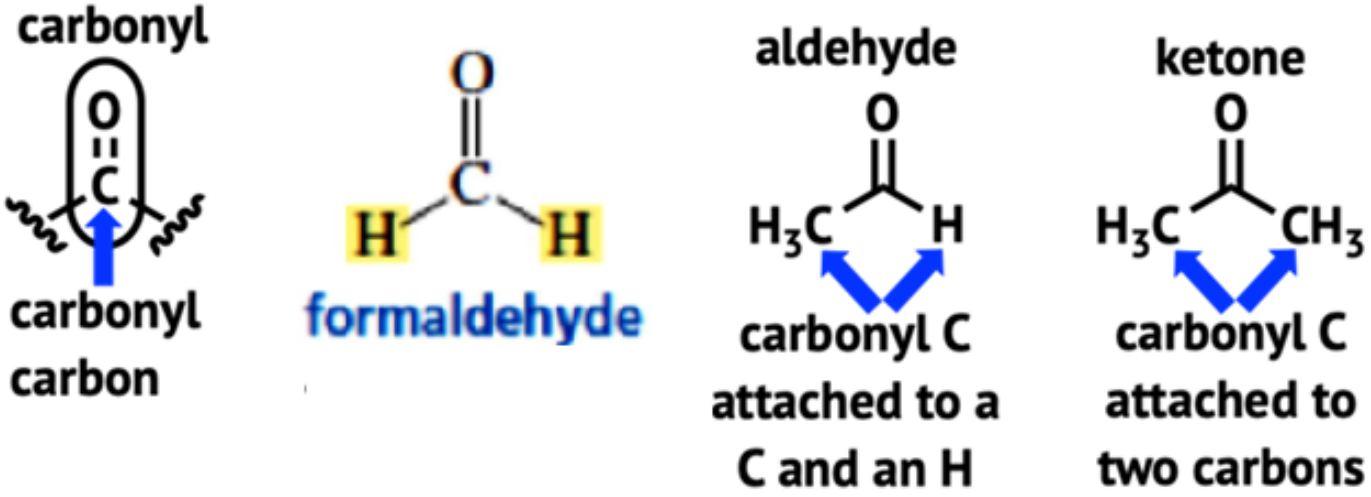
Amides

The R groups modify the properties of

C=O

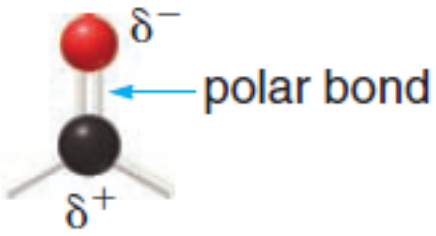
Aldehydes and ketones

- The most important functional group in organic chemistry is the carbonyl group.
- This group is present in aldehydes, ketones, carboxylic acids, esters, and several other classes of compounds.
- The carbonyl carbon (**C=O**) of **formaldehyde**; the simplest aldehyde, is bonded to two **hydrogens**.
- The carbonyl carbon (**C=O**) of all other **aldehydes** is bonded to a hydrogen and to an alkyl group (R).
- The carbonyl carbon of a **ketone** is bonded to two **R** groups.



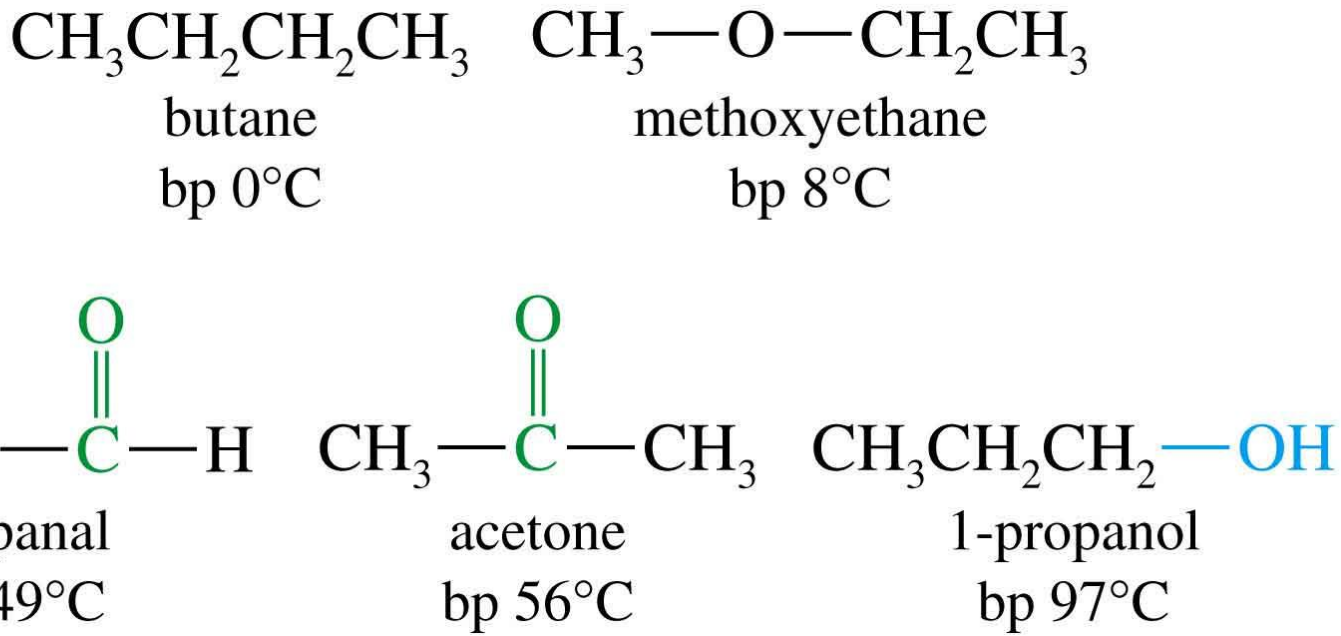
Structure of Aldehydes and Ketones

- Aldehydes (**RCHO**) and **ketones** (**RCOR**) are two families of compounds that contain a carbonyl group.
- Two structural features dominate the properties and chemistry of the carbonyl group.
- Since oxygen is more electronegative than carbon, a carbonyl group is polar.
- The carbonyl **carbon** is electron poor (**δ**+) and the **oxygen** is electron rich (**δ**-).



Boiling Points

- More polar than equivalent alkane.
- Can not form **H-bond** to each other, so lower boiling point than analogous alcohol.



Solubility

- Acetone and acetaldehyde are miscible in water.
- The lower aldehydes and ketones are appreciably soluble in water, because of hydrogen bonding between solute and solvent molecules;
- Aldehydes and ketones are soluble in the usual organic solvents.

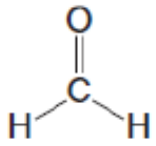
Naming Aldehydes

- In IUPAC nomenclature, aldehydes are identified by the suffix ***-al***.

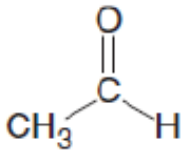
To name an aldehyde using the IUPAC system:

- Find the longest chain containing the CHO group, and change the **-e** ending of the parent alkane to the suffix ***-al***.
- Number the chain or ring to put the CHO group at C_1, but omit this number from the name. Apply all of the other usual rules of nomenclature.

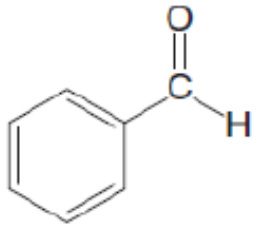
Simple aldehydes have common names that are virtually always used instead of their IUPAC names. Common names all contain the suffix -aldehyde.



formaldehyde
(methanal)



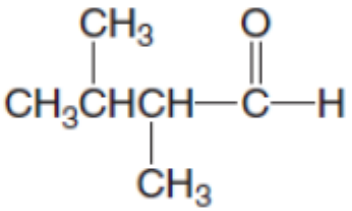
acetaldehyde
(ethanal)



benzaldehyde
(benzenecarbaldehyde)

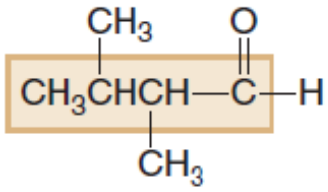
(IUPAC names are in parentheses.)

Example: Give the IUPAC name for the following aldehyde.



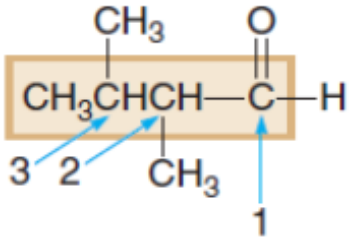
Solution

[1] Find and name the longest chain containing the CHO.



butane (4 C's) ----→ butanal

[2] Number and name substituents, making sure the CHO group is at C_1.



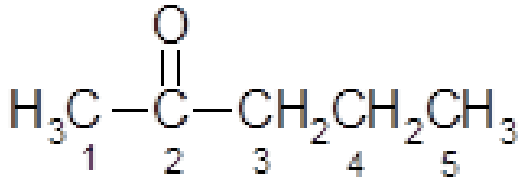
Answer: 2,3-dimethylbutanal

Naming of Ketones

❖ IUPAC (systemic or formal) Names for Ketones

1. Find the longest chain carrying the (**C=O**) group which considered the parent structure and name it by replacing the -***e*** of the corresponding alkane by -***one***.

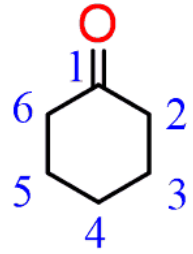
2. Indicate the position of the carbonyl (**C=O**) with a number.
3. Number the chain so that carbonyl carbon has the lowest number.



methyl-n-propyl ketone
2- pentanone
not:- 4- pentanone

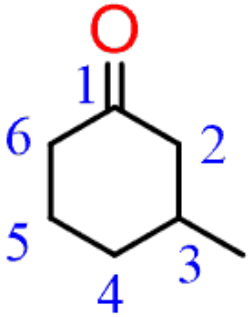
Cyclic ketones

- For cyclic ketones the carbonyl carbon is take the number 1 (C1).



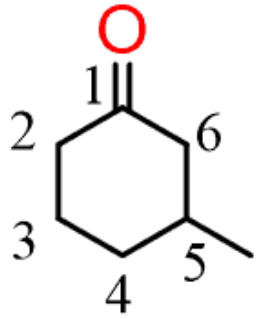
cyclohexanone

- When other groups are present on the ring, it is numbered **clockwise** or **counterclockwise** depending on which direction gives the branch group the lower number:



3-methylcyclohexan-1-one

NOT



5-methylcyclohexan-1-one

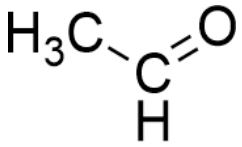
Learning check

✓**Write the structure for the flowing names:**

1. **6-bromo-5,7-dimethyloctanal**
2. **2-hydroxy-3-pentanon**
3. **3-bromo-5-chloro-4-methylhexanal**

Some Common Aldehydes and Ketones

- **Acetaldehyde** boils close to room temperature (bp. 20 ºC).
- Acetaldehyde can be prepared from the oxidation of ethanol.

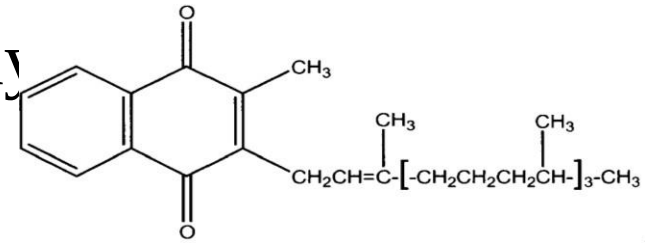


- **Acetone**, the simplest ketone may be prepared using a similar method from the oxidation of propene or from the oxidation of 2-propanol.

- About 30% of the acetone is used directly, because it is not only completely miscible with water but is also an excellent solvent for many organic substances and use in drugs synthesis.

Some Common Aldehydes and Ketones

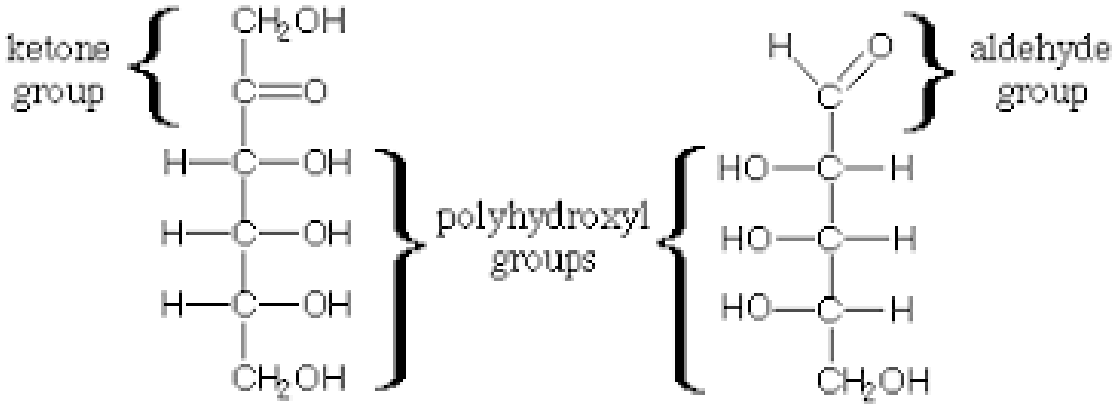
❖ **Quinones** are a unique class of carbony compounds.



Vitamin K structure

- They are cyclic conjugated **diketones**.
- **Vitamin K** is a quinone that is required for the **normal clotting of blood.**

❖ **Carbohydrates** are another class of compounds that have a **ketone** or **aldehyde** functional group.



Role in Medicinal Chemistry

Aldehydes and ketones are found in various biologically active compounds, including:

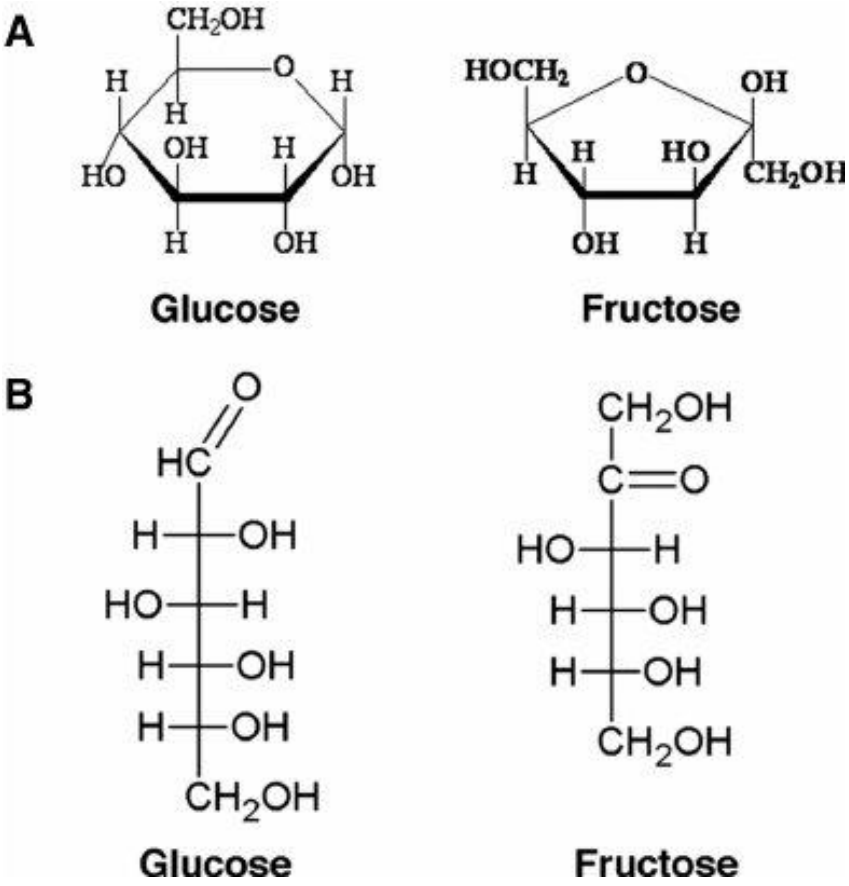
1- Drugs and Pharmaceuticals:

- ✓ **Formaldehyde:** used as a sterilizer and preservative in hospitals and laboratories.
- ✓ **Acetone:** Used as a solvent in drugs.
- ✓ **Corticosteroids:** (e.g., Prednisone, Dexamethasone): Contain

Role in Medicinal Chemistry

2. Natural Biomolecules

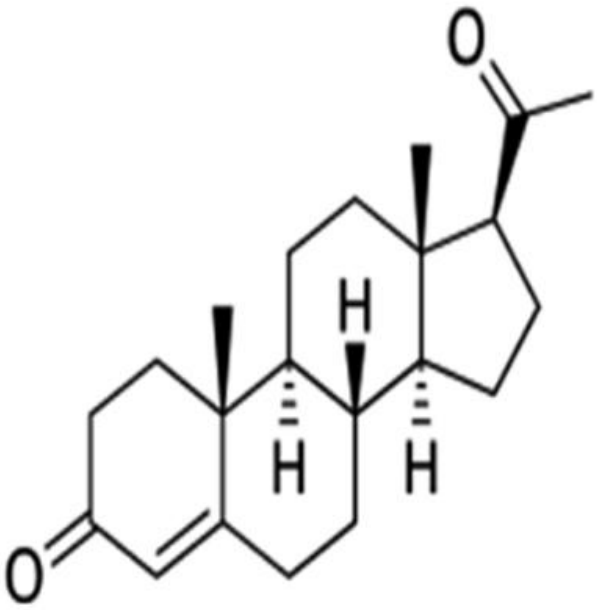
Glucose (an aldehyde sugar) and Fructose (a ketone sugar) play a key role in metabolism.



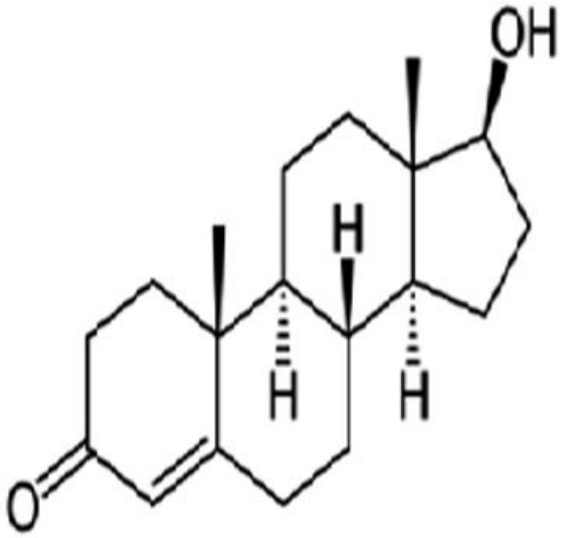
Role in Medicinal Chemistry

3-Steroids and Hormones

(e.g., Testosterone and Progesterone) contain ketone groups.



Progesterone



Testosterone

Clinical Importance of Aldehydes and Ketones

Formaldehyde

- Used as disinfectant and preservative in hospitals.
- **Highly toxic:** causes protein cross-linking and tissue damage.
- Classified as a **carcinogenic compound** with chronic exposure.

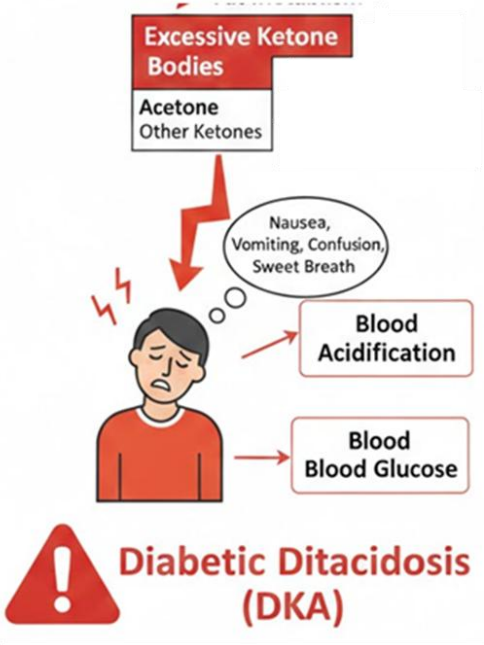
Acetaldehyde (Ethanol metabolism)

- Produced in the liver from ethanol oxidation.
- Responsible for **hangover symptoms** (nausea, headache).
- Contributes to **liver toxicity and inflammation**.

Ketone Bodies

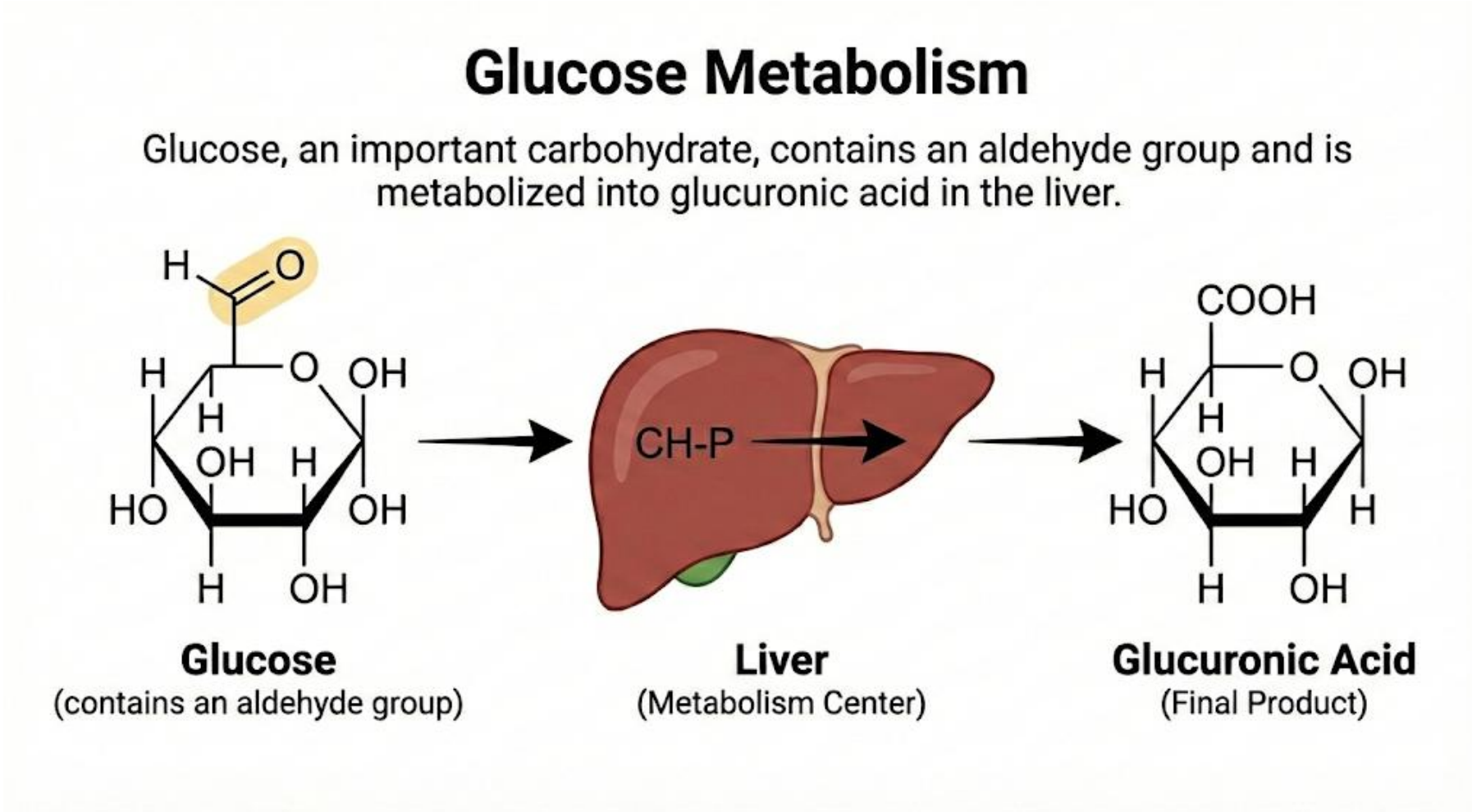
Pyruvate (a ketone derivative) is a key intermediate in the Krebs cycle. Acetone is one of the ketone bodies produced during fat metabolism.

- Raised during fasting and uncontrolled diabetes.
- Excess accumulation leads to **Diabetic Ketoacidosis (DKA)**.



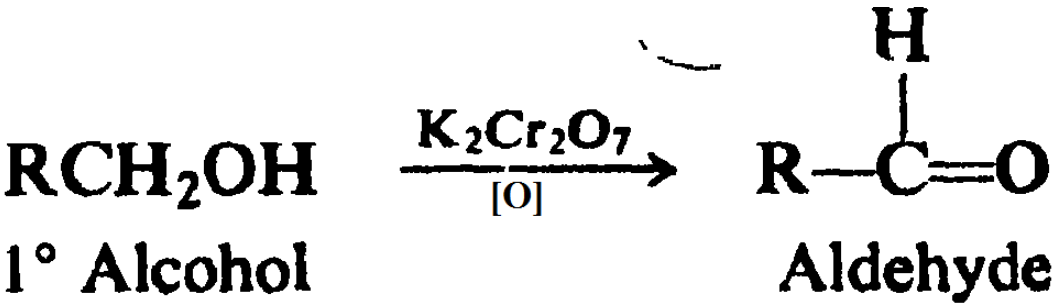
Biological and Medical Importance

1. Glucose Metabolism:

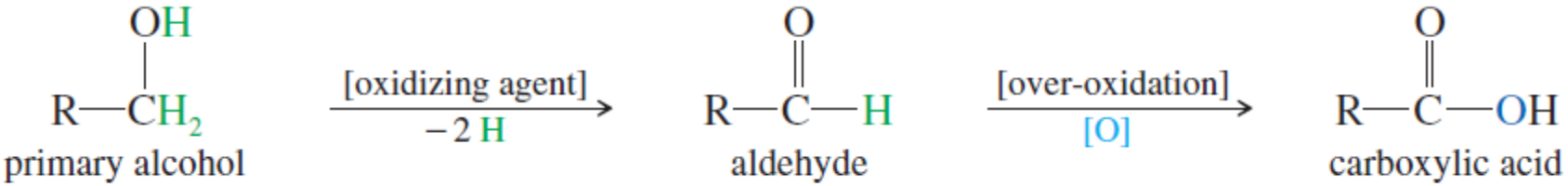


Preparation of aldehydes

1) Oxidation of primary alcohols



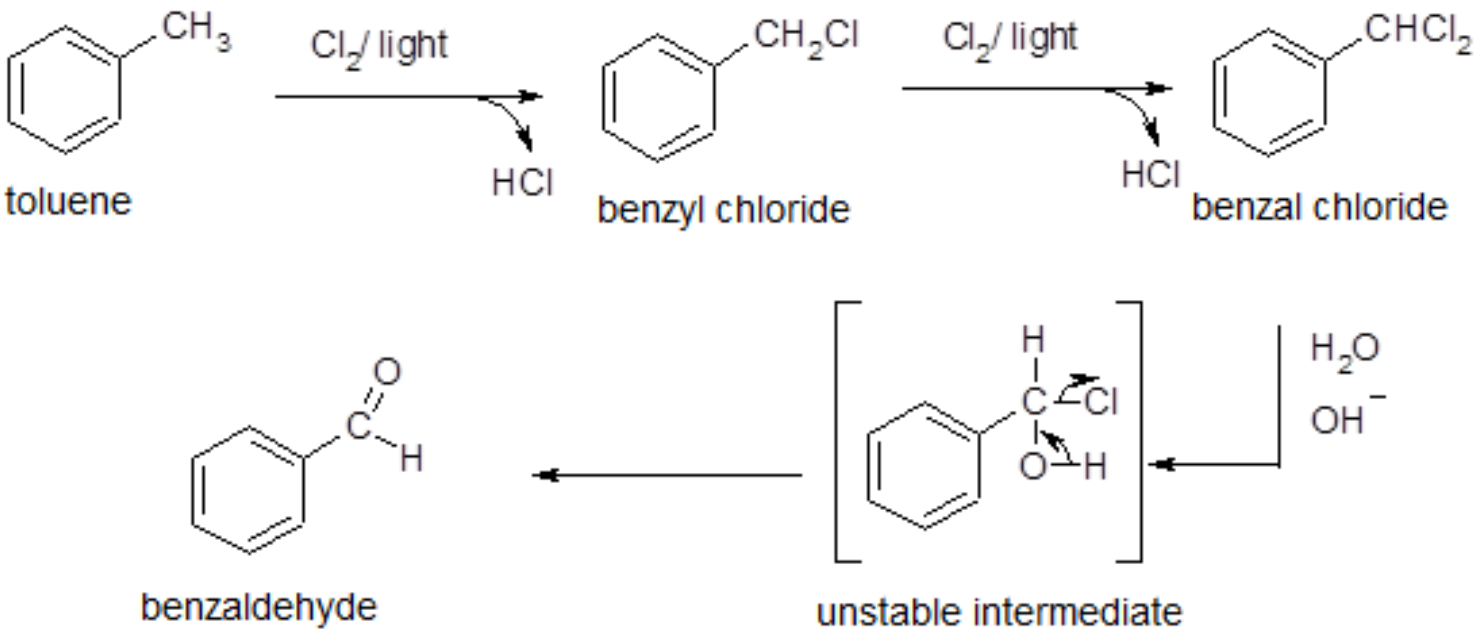
Primary alcohols → aldehydes



Oxidation of a primary alcohol to an aldehyde requires careful selection of an oxidizing agent to avoid over-oxidation to the carboxylic acid.

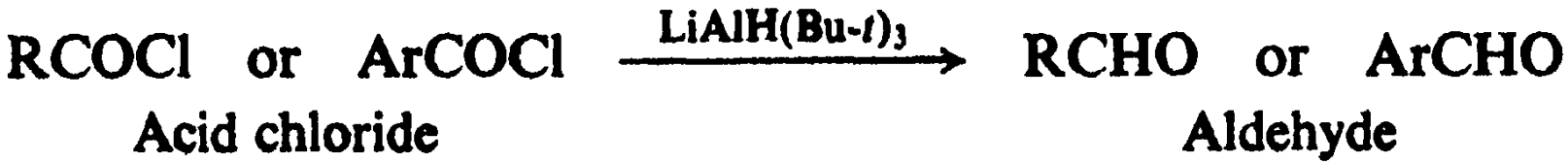
Preparation of aldehydes

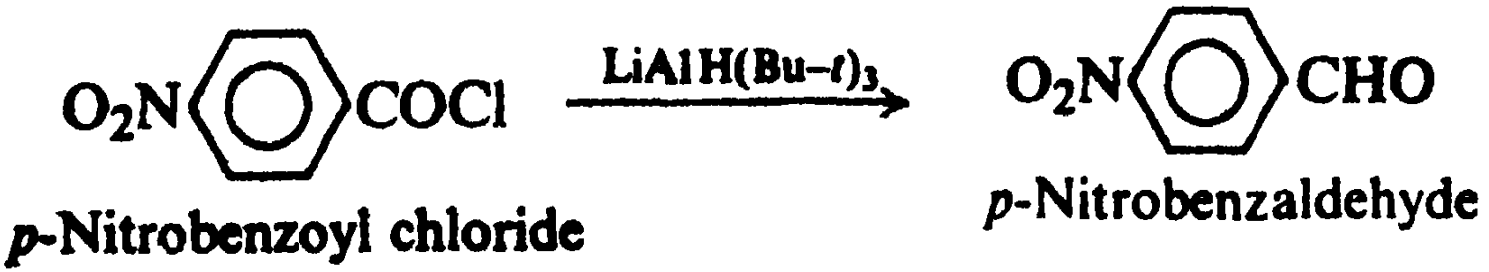
2) Oxidation of methylbenzenes



Preparation of aldehydes

3) Reduction of acid chlorides



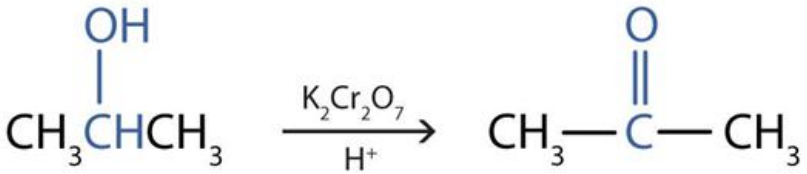


Preparation of Ketones

Preparation of Ketones

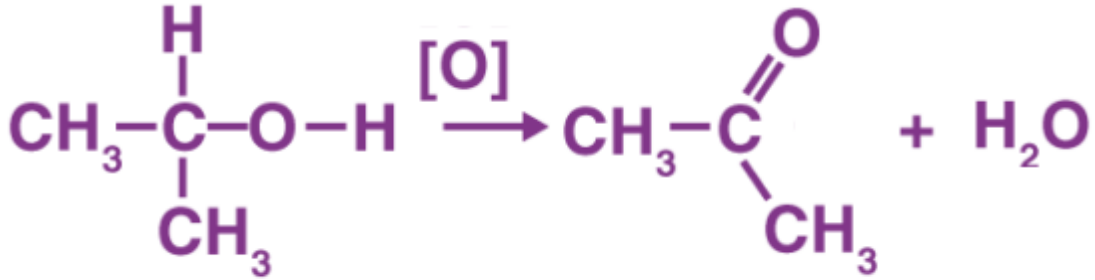
1) Oxidation of secondary alcohols:

Using Potassium dichromate as oxidization reagent



Isopropyl alcohol
(a secondary alcohol)

Acetone
(a ketone)



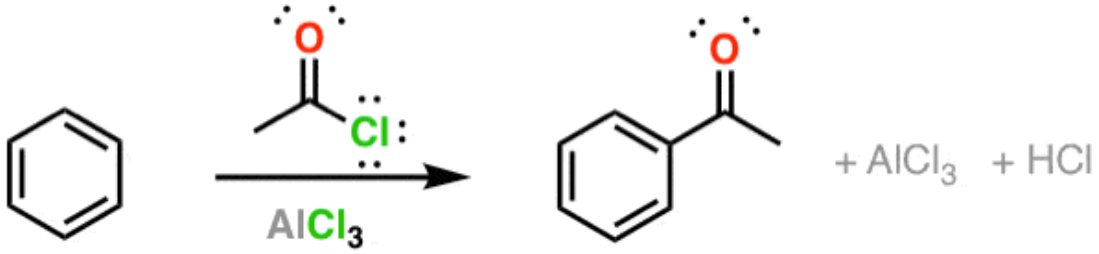
2-Propanol

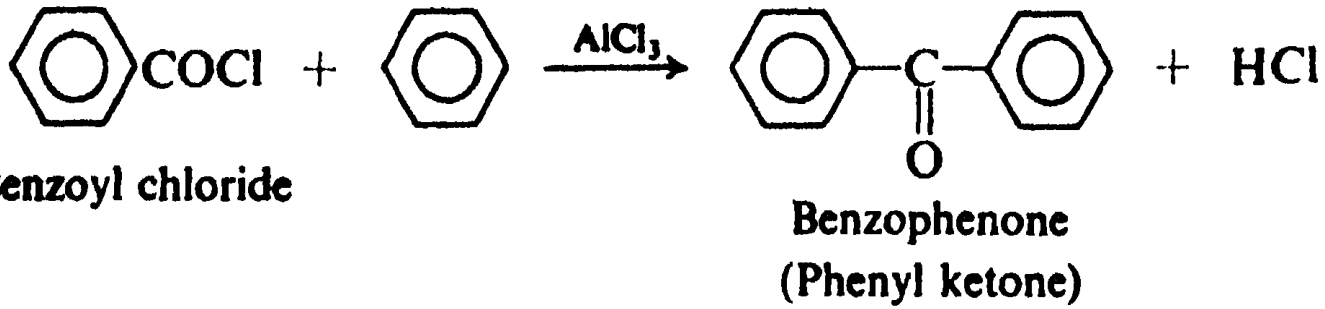
Propanone

Preparation of Ketones

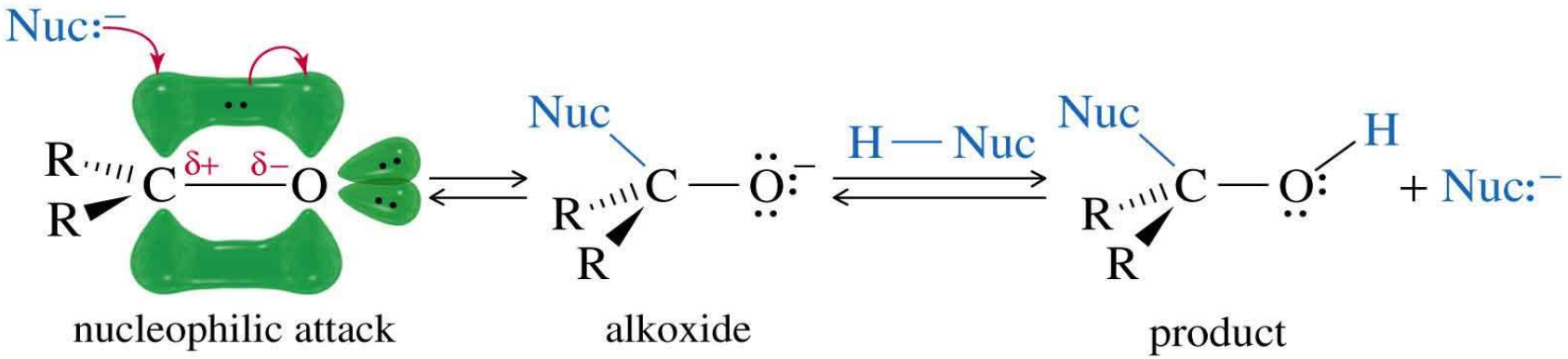
2) Friedel-Crafts acylation:

Friedel–Crafts acylation is an excellent method for making alkyl aryl ketones or diaryl ketones.





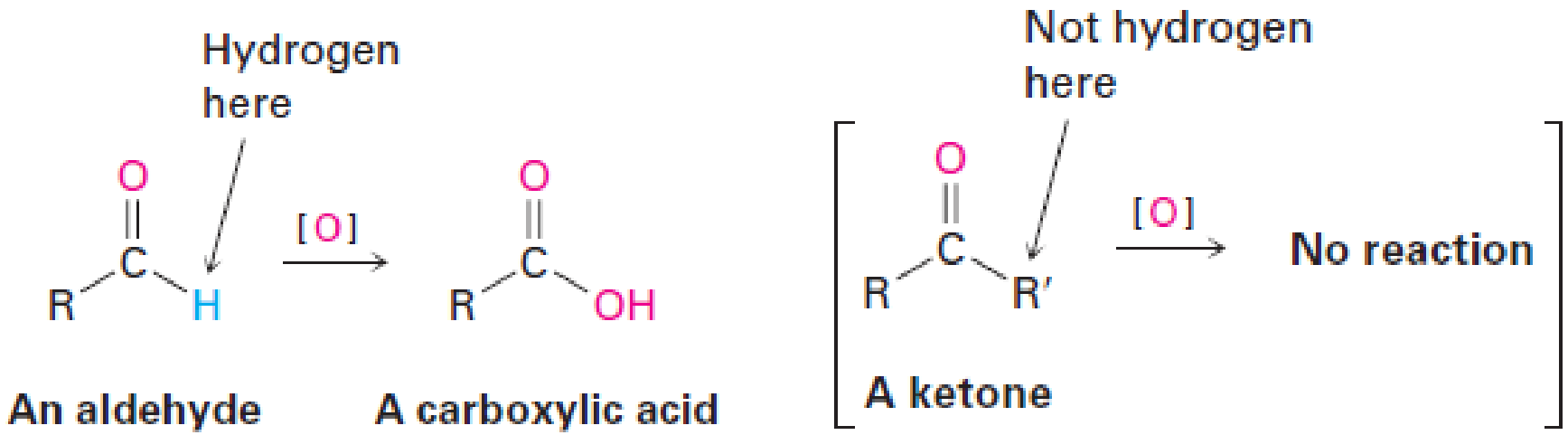
Reaction of aldehydes and ketones (Nucleophilic Addition)



Reactions of aldehydes and ketones

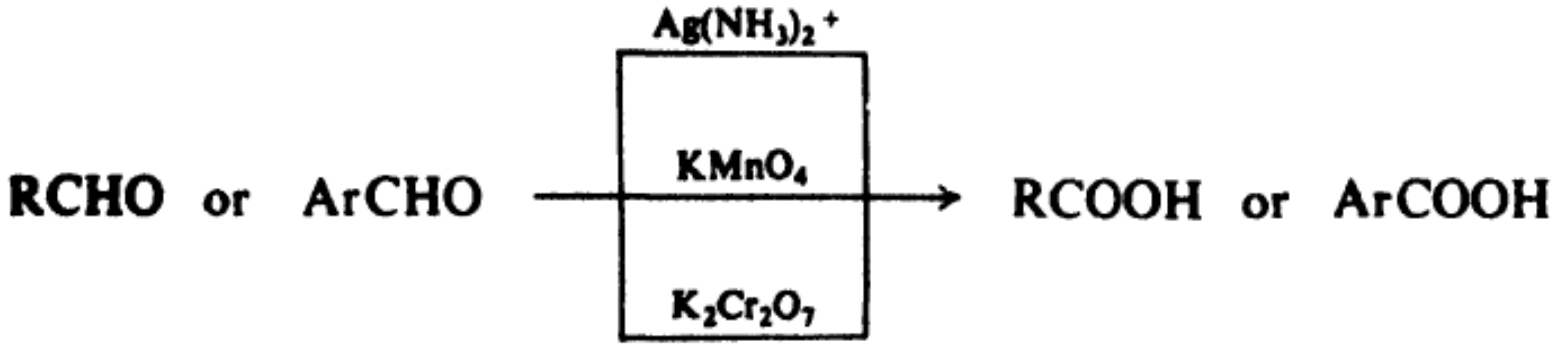
1) Oxidation of Aldehydes:

- ***Aldehydes are easily oxidized to yield carboxylic acids***, but ketones are unreactive toward oxidation.
- This reactivity difference is a consequence of structure: aldehydes have a CHO proton that can be removed during oxidation, but ketones do not.



Oxidation of Aldehydes:

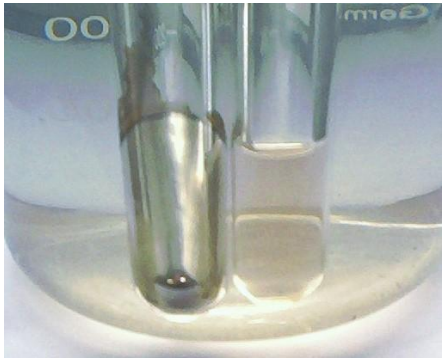
(a) Aldehydes



- **This reaction is Used specially for detection of Aldehydes**
  - **Tollens`test**

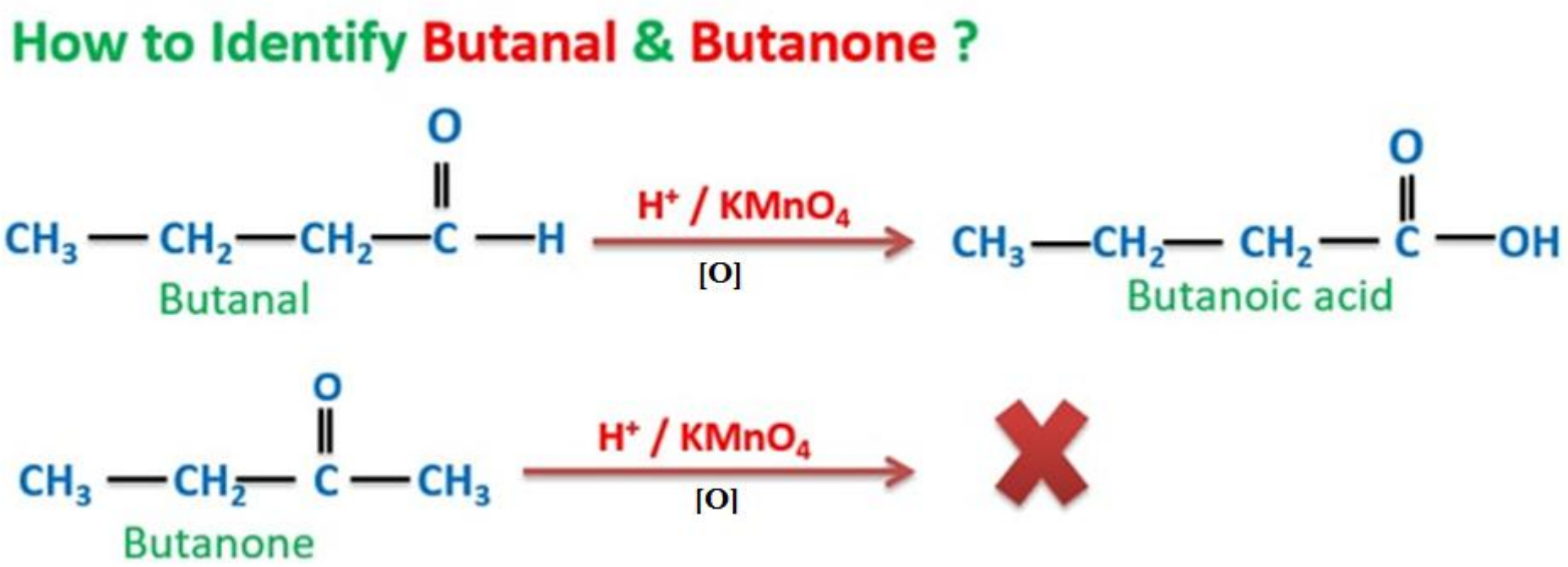
$$CH_3CHO + 2Ag(NH_3)_2^+ + 3OH^- \longrightarrow 2Ag + CH_3COO^- + 4NH_3 + 2H_2O$$

Colorless solution → *Silver mirror*



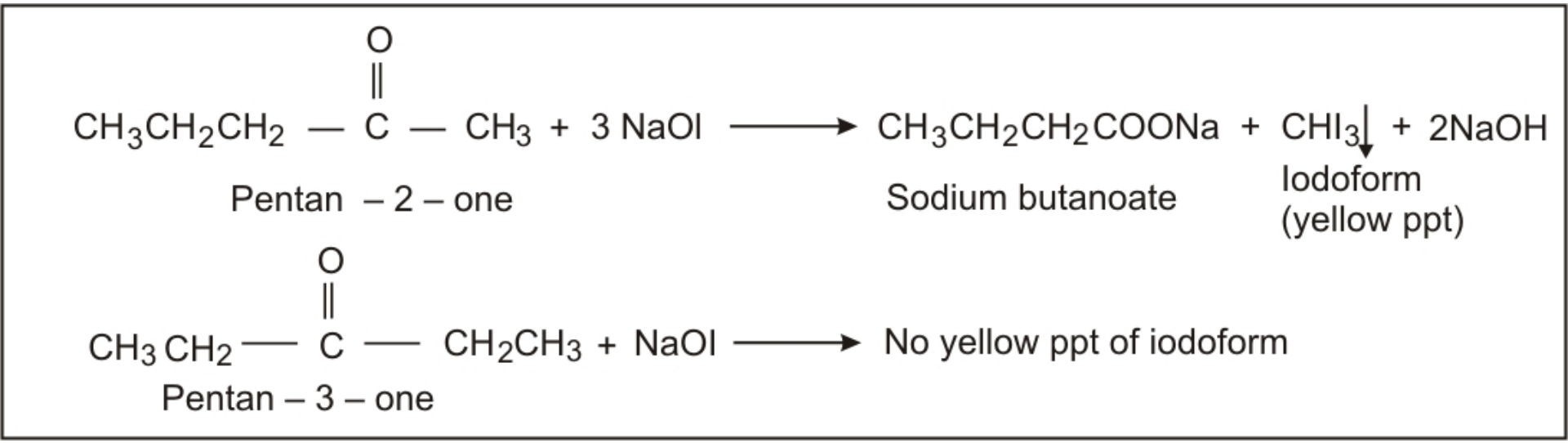
Difference between ketones and aldehydes

- We can use: **Potassium manganate** (VII) $KMnO_4$ to distinguish between aldehydes and ketones



Q: Give simple chemical tests to distinguish between the following pairs of compounds:

- **Pentan-2-one and Pentan-3-one**



Comparison Between Aldehydes and Ketones

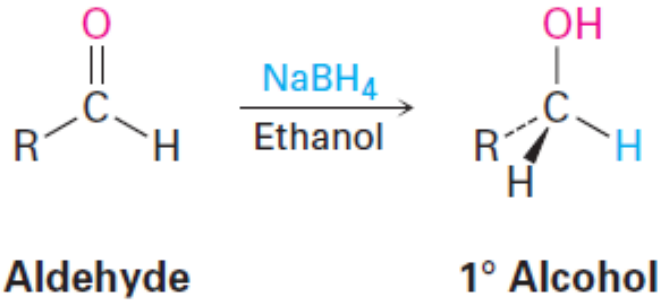
Feature	Aldehydes	Ketones
Oxidation	Easily oxidized	Resistant
Tollens' Test	Positive	Negative
Carbonyl Carbon	More reactive	Less reactive
Biological Example	Glucose, **Retinal**	Ketone bodies
Toxicity	Generally higher	Lower

2) Reduction reactions for aldehydes and ketones

2) Reduction of C=O

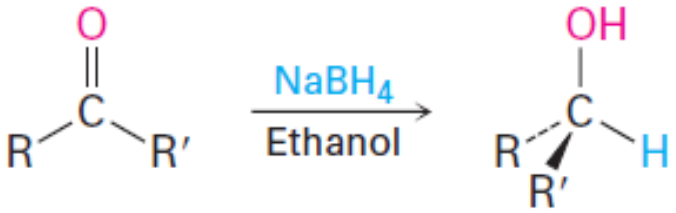
a) Reduction to alcohols:

- ✓ **Aldehydes are reduced with sodium borohydride (NaBH4) to give primary alcohols:**



Aldehyde **1° Alcohol**

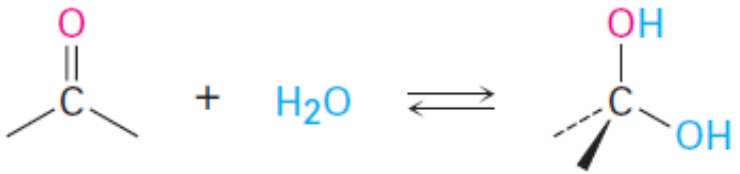
- **ketones are similarly reduced to give secondary alcohols.**



Ketone **2° Alcohol**

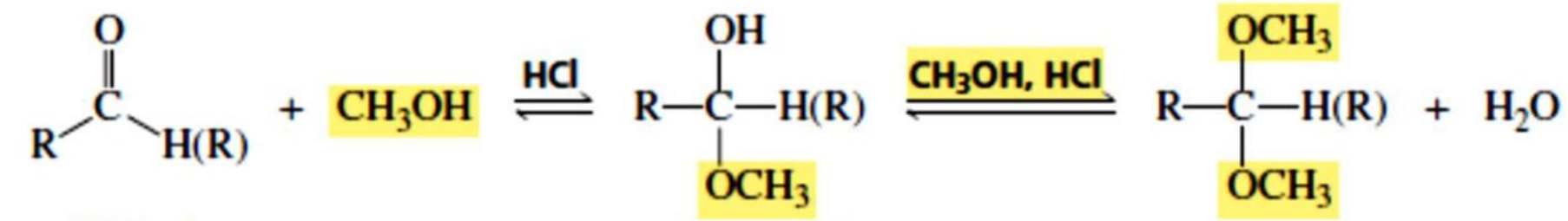
3) Addition of Water

- Aldehydes and ketones undergo a nucleophilic addition reaction with water to yield the corresponding carbonyl hydrates, sometimes called **(gem diols)**



Aldehyde or ketone — **Carbonyl hydrate (gem diol)**

4) Addition of Alcohol



an aldehyde or a ketone — **a hemiacetal** — **an acetal**

Cyclization of Monosaccharides

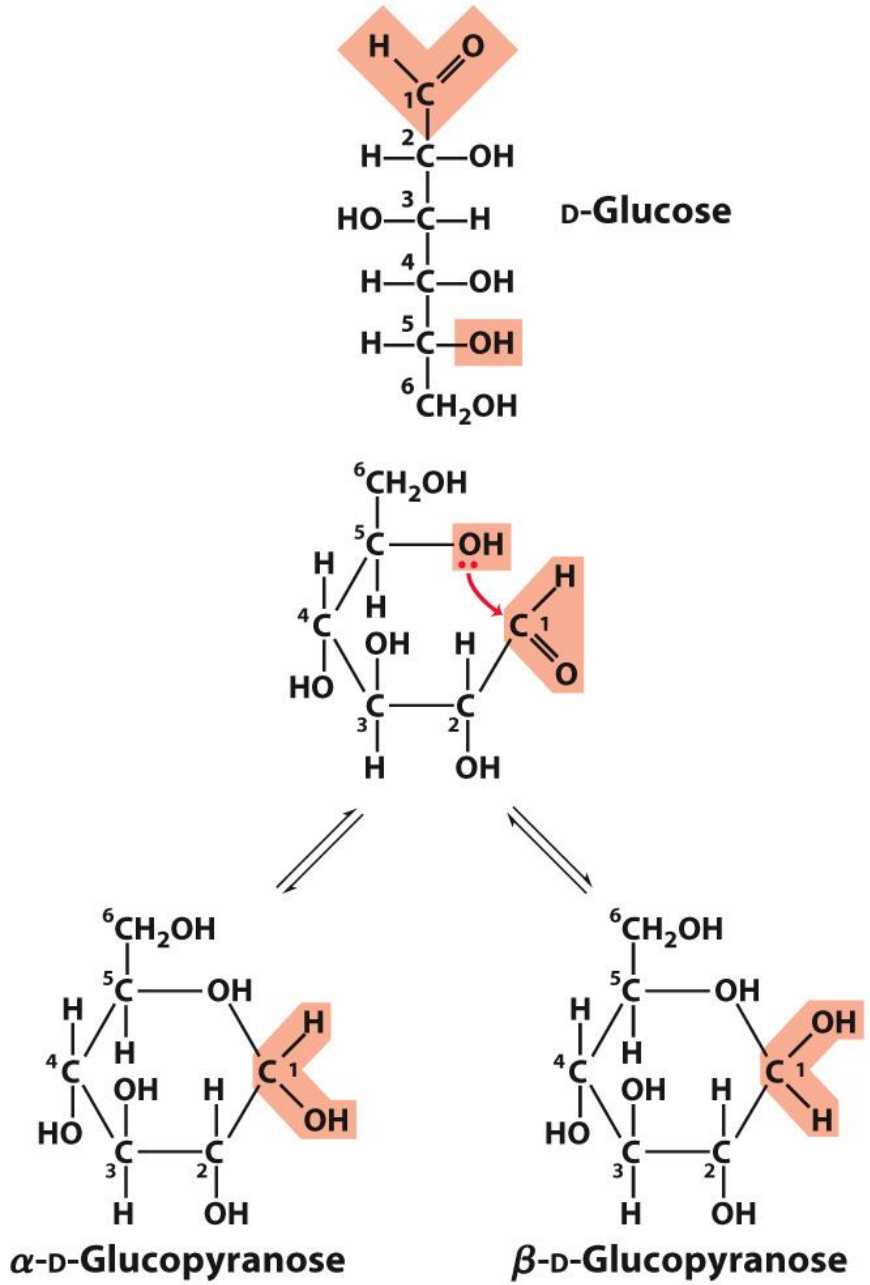


Figure 7-6
Lehninger Principles of Biochemistry, Seventh Edition

- The nucleophilic alcohol attacks the electrophilic carbonyl carbon, allowing formation of a **hemiacetal**.
- As a result, the linear carbohydrate forms a ring structure.
- At the completion of this structure, the **carbonyl** carbon **is** reduced to an **alcohol**

Homework

- Why aldehydes are more toxic than ketones?
- Why ketone bodies increase in diabetes?
- Why formaldehyde causes protein cross-linking?