# CAIE Chemistry A-level

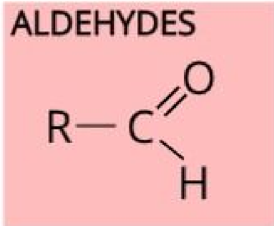
## 17: Carbonyl Compounds

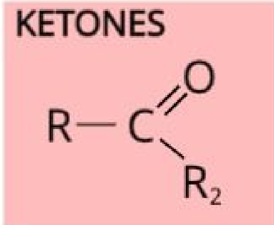
Notes

## Aldehydes and Ketones

**Aldehydes** and **ketones** both contain the carbonyl group, C=O.
The **position** of the **carbonyl** group in the carbon chain is **different** in aldehydes and ketones.

The carbonyl group is at the end of the carbon chain in aldehydes and in the middle in ketones. The suffix for aldehydes is **-al** and the suffix for ketones is **-one**.




### Formation of Aldehydes and Ketones

Aldehydes and ketones are formed when alcohols are **oxidised** using **acidified potassium dichromate(VI)** ($Cr_2O_7^{2-}/H^+$).

Aldehydes are formed from **primary** alcohols, whereas ketones are formed from **secondary** alcohols.

Primary alcohols

**Primary** alcohols can be **partially oxidised** to **aldehydes**.

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

If the aldehyde undergoes **further oxidation**, **carboxylic acids** are produced.

$$CH_3CHO + [O] \rightarrow CH_3COOH + H_2O$$

The full oxidation reaction can be written as:

$$CH_3CH_2OH + 2[O] \rightarrow CH_3COOH + 2H_2O$$

If you are only collecting the aldehyde, carry out the reaction with excess alcohol and distill off the aldehyde as soon as it forms to prevent further oxidation.

Secondary alcohols

**Secondary** alcohols are oxidised to **ketones**. No further oxidation can take place.

$$CH_3C(OH)HCH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$$

### Reduction of Aldehydes and Ketones

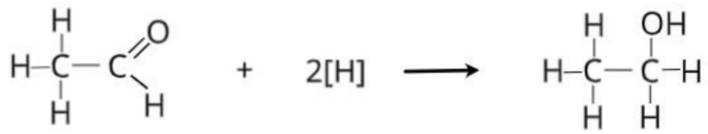
A **reducing agent** can be used to reverse the reactions above and convert aldehydes and ketones back to primary and secondary alcohols.

Typically $LiAlH_4$ or $NaBH_4$ (dissolved in water with methanol) are used as reducing agents for this reaction.

**Reduction of Aldehydes**

$$RCHO + 2[H] \rightarrow RCH_2OH$$

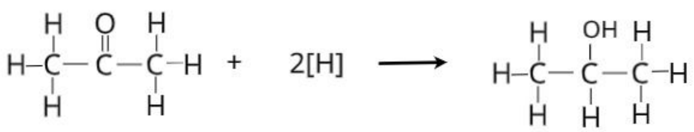
For example, the reduction of **ethanal to ethanol**:



**Reduction of Ketones**

$$R_1COR_2 + 2[H] \rightarrow RC(OH)HR_2$$

For example, the reduction of **propanone to propanal**:

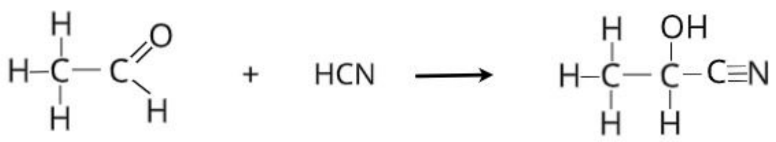


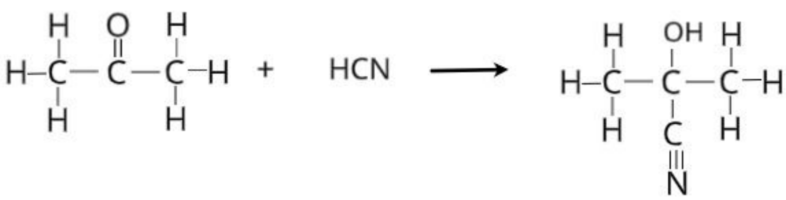
## Reaction with HCN and KCN

Hydrogen cyanide reacts with aldehydes and ketones to produce **hydroxynitrile compounds** by removing the C=O double bond. The reaction is called **nucleophilic addition** (see the mechanism on the following page).

*Naming:*

When naming a hydroxynitrile, the **carbon in the nitrile group (C≡N)** is referred to as the **first carbon** so the position of groups (including the alcohol group) is counted from there. In the equations below, the product of the first reaction is **2-hydroxypropanenitrile** and the product of the second reaction is **2-hydroxy-2-methylpropanenitrile**.





HCN is a very **poisonous gas.** Often **KCN** or **NaCN** are reacted with acid to form HCN in situ.

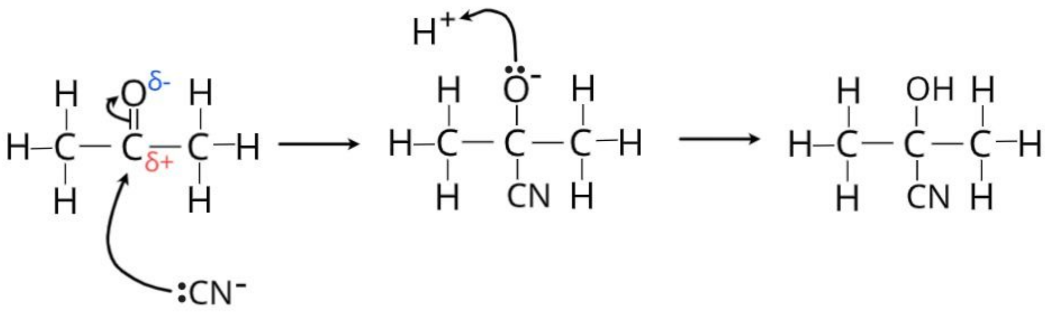
## Nucleophilic Addition Reactions

When aldehydes and ketones react with HCN to form **hydroxynitriles**, a **nucleophilic addition** reaction occurs. A nucleophile is an **electron pair donor**.

The Mechanism:

The **carbonyl bond** (C=O) is **highly polar**. The negative **cyanide ion** acts as a **nucleophile** and attacks the slightly positive carbon atom. The C=O bond breaks, leaving only a **single bond** between the **carbon and oxygen** atoms.

The negatively charged oxygen then bonds to a **hydrogen ion** (from HCN or any added acid).



## Detecting Carbonyl Compounds

The carbonyl group can be detected using 2,4-dinitrophenylhydrazine (2,4-DNPH).

When 2,4-DNPH is added to a solution of aldehyde or ketone, a **yellow/ orange precipitate** is produced. The formation of this coloured precipitate indicates the presence of a **C=O carbonyl group**.

## Distinguishing between Aldehydes and Ketones

Simple tests can be carried out to detect whether a compound is an aldehyde or a ketone. **Ketones** are **not easily oxidised** whereas **aldehydes** are **easily oxidised** to carboxylic acids.

After identifying a solution as a carbonyl using 2,4-DNPH, certain reactions can be carried out using **oxidising agents**. A **positive result** indicates that an **aldehyde** is present while a **negative result** suggests a **ketone** is present.

Acidified potassium dichromate(VI)

**Aldehyde** - orange solution turns green.

**Ketone** - no visible change / solution remains orange.

Tollen's reagent

**Aldehyde** - silver mirror forms on the walls of the test tube.

**Ketone** - no visible change.

Fehling's reagent

**Aldehyde** - blue solution gives a brick red precipitate.

**Ketone** - no visible change / solution remains blue.

**Deducing the Presence of $CH_3CO$- Group**

A $CH_3CO$- group can be detected using **alkaline aqueous iodine,** $I_2$.

**Iodine** is added to the carbonyl, followed by **sodium hydroxide** (to make the solution alkaline). If the $CH_3CO$- group is present, a **yellow precipitate** of **tri-iodomethane** ($CHI_3$) will form.

$$CH_3COR + 3I_2 + 4NaOH \rightarrow RCOONa + CHI_3 + 3NaI + 3H_2O$$