6.2.4 Carbon–carbon bond formation

Various reactions are used to involve formation of a C–C bond in synthesis to increase the length of a carbon chain

Nucleophilic substitution of haloalkanes with cyanide ions

| Change in functional group: haloalkane → nitrile | Reagent: KCN dissolved in ethanol/water mixture |
| Conditions: Heating under reflux | Mechanism: Nucleophilic substitution |
| Type of reagent: Nucleophile, :CN⁻ |

This reaction increases the length of the carbon chain (which is reflected in the name) in the above example butanenitrile includes the C in the nitrile group.

Naming Nitriles

Nitrile groups have to be at the end of a chain. Start numbering the chain from the C in the CN

- CH₂CH₂CN : propanenitrile
- H₃C–CH–CH₂–C≡N 3-methylbutanenitrile

Note the naming: butanenitrile and not butannitrile.

Addition of hydrogen cyanide to carbonyls to form hydroxynitriles

| Reaction: carbonyl → hydroxynitrile | Reagent: sodium cyanide (NaCN) and dilute sulfuric acid. |
| Conditions: Room temperature and pressure | Mechanism: nucleophilic addition |

The NaCN supplies the nucleophilic CN⁻ ions. The H₂SO₄ acid supplies H⁺ ions needed in the second step of the mechanism.

When naming hydroxy nitriles the CN becomes part of the main chain.

We could use HCN for this reaction but it is a toxic gas that is difficult to contain. The KCN/NaCN are still, however, toxic, because of the cyanide ion.
The nitriles made in the previous two reactions can then be converted into other functional groups by the following reactions

### Preparing amines from nitriles

Reduce nitrile to amine by using LiAlH₄ in ether or by reducing with H₂ using a Ni catalyst

\[
\text{CH}_3\text{CH}_2\text{CN} + 4[H] \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2
\]

This is a reduction reaction

### Preparing carboxylic acids from nitriles

Hydrolysing nitriles by reacting them with strong acids will produce a carboxylic acid

\[
\text{CH}_3\text{CH}_2\text{CN} + \text{H}^+ + 2\text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}_2\text{CO}_2\text{H} + \text{NH}_4^+
\]

This is a hydrolysis reaction

C-C bonds can be added to aromatic compounds through the Friedel-Craft's Reactions met in 6.1.1 aromatic compounds

### Friedel Crafts Alkylation

**Change in functional group:** benzene \(\rightarrow\) alkylbenzene

**Reagents:** chloroalkane in the presence of anhydrous aluminium chloride catalyst

**Conditions:** heat under reflux

**Mechanism:** Electrophilic substitution

Any chloroalkane can be used RCl where R is any alkyl group e.g. \(-\text{CH}_3\), \(-\text{C}_2\text{H}_5\).

The electrophile is the \(\text{R}^+.\)

**Formation of the electrophile.**

\[
\text{AlCl}_3 + \text{CH}_3\text{CH}_2\text{Cl} \rightarrow \text{CH}_3\text{CH}_2^+ \text{AlCl}_4^-
\]

**Overall Equation for reaction**

\[
\text{CH}_3\text{CH}_2^+ \text{AlCl}_4^- + \begin{array}{c}
\text{C} \\
\end{array} \rightarrow \begin{array}{c}
\text{C} \\
\text{CH}_2\text{CH}_3
\end{array} + \text{AlCl}_3 + \text{HCl}
\]

### Friedel Crafts Acylation

**Change in functional group:** benzene \(\rightarrow\) phenyl ketone

**Reagents:** acyl chloride in the presence of anhydrous aluminium chloride catalyst

**Conditions:** heat under reflux \((50^\circ\text{C})\)

**Mechanism:** Electrophilic substitution

Any acyl chloride can be used RCOCl where R is any alkyl group e.g. \(-\text{CH}_3\), \(-\text{C}_2\text{H}_5\).

The electrophile is the \(\text{RCO}^+.\)

**Equation for Formation of the electrophile.**

\[
\text{AlCl}_3 + \text{CH}_3\text{COCl} \rightarrow \text{CH}_3\text{CO}^+ \text{AlCl}_4^-
\]

**Overall Equation for reaction**

\[
\text{CH}_3\text{CO}^+ \text{AlCl}_4^- + \begin{array}{c}
\text{C} \\
\end{array} \rightarrow \begin{array}{c}
\text{C} \\
\text{CO} \\
\text{CH}_3
\end{array} + \text{AlCl}_3 + \text{HCl}
\]

These are important reactions in organic synthesis because they introduce a reactive functional group on to the benzene ring