# Cambridge (CIE) A Level Chemistry

Your notes

## Formulas, Functional Groups & the Naming of Organic Compounds

### Contents




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# Functional Groups of Organic Compounds (AL)

- Many organic compounds contain one or more **functional groups**
- A functional group is an **atom** or **group of atoms** in an organic molecule, that determines its **characteristic chemical** and **physical properties**

## Arenes

- Arenes are **aromatic compounds** that contain a **benzene ring**

### The arene functional group


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### Chemical properties

- Due to the delocalised electron ring (π system of electrons), these compounds are **electron-rich** and therefore can undergo **electrophilic attack** under the right conditions
- However, because the delocalised electron ring system makes benzene so stable, it is **resistant to addition reactions**
- This is very different to alkenes, which are very reactive and readily undergo addition reactions

### Physical properties

- Benzene has van der Waals dispersion forces of attraction between the molecules and has a boiling point of 80 C
- The presence of the **non-polar** hydrocarbon part in the arene functional group means that these compounds are often insoluble in water
- Benzene would have to break many hydrogen bonds between the water molecules to be soluble in water, which does not happen as it is not energetically favourable

## Halogenoarenes

- These are **aromatic compounds** that contain a **halogen** bonded to a **benzene ring**

### The halogenoarene functional group

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- They are also known as aryl halides

## Chemical properties

- These compounds are also prone to **electrophilic attack** because of the π system of delocalised electrons
- The halogens can also take part in **substitution reactions**

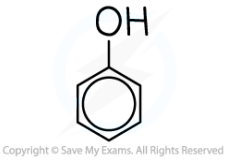
## Physical properties

- Chlorobenzene, bromobenzene and iodobenzene are all liquid at room temperature with an oily texture
- As you might expect, the boiling points increase as the size of the halogen attached increases, because the number of electrons within the molecule increases
- Like other arenes, halogenoarenes are **insoluble in water** because of the **non-polar** hydrocarbon part of the ring
- These molecules are large relative to the size of water molecules, and as with the arenes it is not energetically favourable for the halogenoarene molecules to break the hydrogen bonds between the water molecules, so it does not happen

# Phenols

- Phenols are another type of **aromatic compounds** containing a **hydroxide** bonded to a **benzene ring**

## The phenol functional group



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## Chemical properties

- The -OH group in phenols is more **acidic** than in alcohols as the oxygen donates one of its lone pairs of electrons into the ring system
- This causes an increased electron density of the ring, causing it to become much more reactive than benzene itself
- It also makes it easier for the hydrogen of the -OH group to be donated
- Phenols can also react with **reactive metals** such as sodium to form **alkoxide ions**

## Physical properties

- Phenol is a white, crystalline solid, and it has a disinfectant-like smell
- Due to the -OH group in phenols, they can form hydrogen bonds with water molecules, and therefore to a degree phenol is soluble in water

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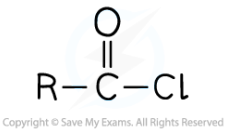
# Acyl chlorides

- Acyl chlorides are (carboxylic) **acid derivatives** containing:
  - A **chlorine atom** attached to a C=O group (replacing what would have been the -OH group of a carboxylic acid)
  - An **acyl** (hydrocarbon) group attached to a C=O group

## The acyl chloride functional group



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- Acyl chlorides are also known as 'acid' chlorides

## Chemical properties

- They are fuming liquids and are colourless, with a strong smell
- Acyl chlorides are **extremely reactive** and readily take part in **substitution** reactions in which the chlorine atom is substituted by other species
- This reactivity is why they are fuming liquids and why they have such a strong smell - they react with any water vapour in the air

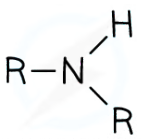
## Physical properties

- Acyl chlorides react **violently** with water, so we cannot say whether or not they would be soluble in water

# Amines

- Amines are compounds with the $-NH_2$ (primary amine), -NH (secondary amine) or -N (tertiary amine) group

## The amine functional group



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- Classification of amines
  - In primary amines, the N of the amine group is bonded to one R group (and two hydrogen atoms)
  - In secondary amines, the N of the amine group is bonded to two R groups (and one hydrogen atom)
  - In tertiary amines, the N of the amine group is bonded to three R groups

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## Chemical properties

- Due to the lone pair of electrons on the nitrogen, amines are **basic compounds**

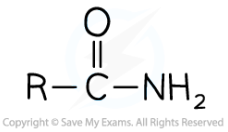
## Physical properties

- The lone pair on the N of the amine group means that they can form hydrogen bonds
- They are often **soluble in water** because they form hydrogen bonds with water molecules
- The smaller amines are very soluble in water, but their solubility decreases as the non-polar hydrocarbon chain gets longer
- They often have a fishy smell, especially as the size of the amines increases

# Amides

- Amides are compounds containing:
  - An amine ($-NH_2$) group
  - A carbonyl group (C=O)
  - The amide group is $-CONH_2$

## The amide functional group



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## Chemical properties

- Amides are less **basic** than amines, as the lone pair of electrons on the nitrogen is **delocalised**

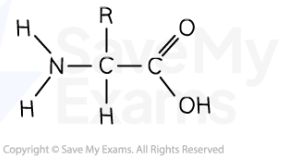
## Physical properties

- Amides are often **soluble in water** as they can form hydrogen bonds with water molecules
- The smaller amides are very soluble in water, but their solubility decreases as the non-polar hydrocarbon chain gets longer

# Amino Acids

- Amino acids are the building blocks of proteins and consists of:
  - An amine ($-NH_2$) group
  - A carboxyl ($-COOH$) group

## The α-amino acid functional group



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## Chemical properties

- Amino acids react with bases to form **salts**
- They also react with alcohols to form **esters**
- The reaction of amino acids with amines gives **amides**

## Physical properties

- Most of the amino acids are **soluble** in water but **insoluble** in **organic solvents**
- Amino acids have **chiral centres** and exhibit **optical isomers** (except for glycine)

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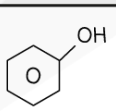
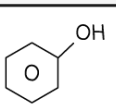
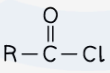
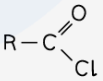
# Formulae of Organic Compounds (AL)

- Students are expected to interpret and use the following formulae of organic compounds
  - General formula
  - Structural formula
  - Displayed formula
  - Skeletal formula

## Formulae of organic compounds table

| Functional Group | General Formula | Structural Formula | Displayed Formula | Skeletal Formula |
|---|---|---|---|---|
| Arene | $C_nH_{2n-6m}$ (number of C atoms; number of rings) |  | N/A |  |
| Halogenoarene | $C_nH_{2n-7m}X$ |  | N/A |  |
| Phenol | $C_nH_{2n-7m}OH$ |  | N/A |  |
| Acyl chloride | RCOCl |  |  |  |

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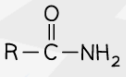
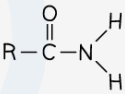
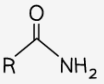
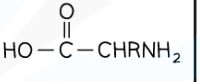
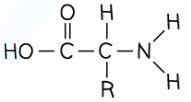
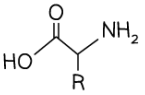
| | | | | |
|---|---|---|---|---|
| Amine | $C_nH_{2n+3}N$ |  |  |  |
| Amide | $RCONH_2$ |  |  |  |
| Amino Acid | $HOOCCHRNH_2$ |  |  |  |

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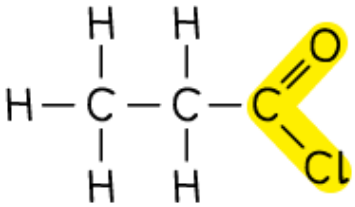
# Nomenclature of Aliphatic Compounds (AL)

- Students are required to use **systematic nomenclature** of simple **aliphatic compounds**
- The following method can be applied when naming organic compounds:
  - Identify the longest carbon chain containing the functional group
  - Identify the functional group on the chain to determine the suffix or prefix on the compound
  - Count along the carbon chain such that the functional group has the **lowest number**
  - Add any **side chains** or lower priority functional groups as **prefixes** to the beginning of the name in **alphabetic order**
  - Use the prefixes di-, tri- and tetra- if there are **two or more identical functional groups** or **side chains**

## Nomenclature of simple aliphatic organic molecules with functional groups table

| Functional group | Example | Name |
|---|---|---|
| **Acyl chloride** |  | Propanoyl chloride |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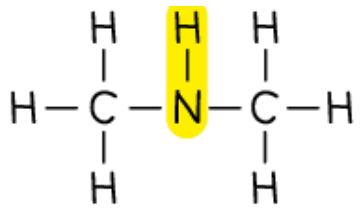
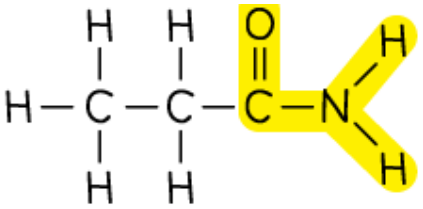
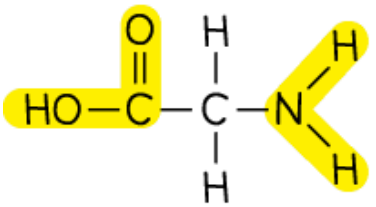
| | | |
|---|---|---|
| **Amine** |  | Dimethylamine |
| **Amide** |  | Propanamide |
| **Amino acid** |  | 2-aminoethanoic acid |

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# Nomenclature of Aromatic Compounds

- The method used to name **aromatic compounds** is similar to that of **aliphatic compounds**
- Students are required to use systematic nomenclature of simple aromatic molecules with one benzene ring and one or more **simple substituents**

## Nomenclature of simple aromatic organic molecules with functional groups table

| Functional group | Example | Name |
|---|---|---|


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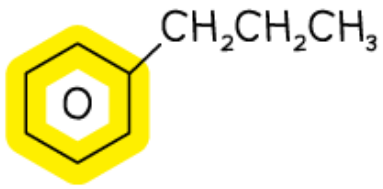
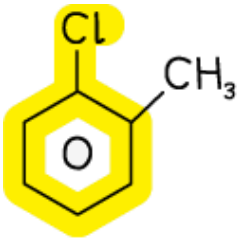
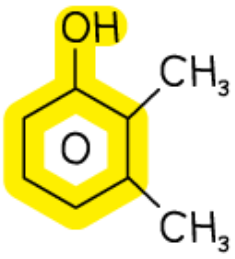
| | | |
|---|---|---|
| **Arene** |  | Propyl benzene |
| **Chlorobenzene** |  | 2-methylchlorobenzene |
| **Phenol** |  | 2,3-dimethyl phenol |

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