# Gr. 12 Organic Chemistry Cheat Sheet

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## Introduction

The term *organic* generally means **"something made from the earth"** or **"not chemically synthesized."**

*Organic chemistry* refers to the **study of compounds that contain carbon atoms as the principal element.**

The **simplest organic compounds** are ***hydrocarbons*** made from C and H atoms

Despite the term *organic* generally meaning "natural," organic compounds **can in fact be chemically synthesized** (first synthesized organic compound was **urea** - found in mammal urine)

Carbon has a **bonding capacity of 4** so each C atom must **always make 4 bonds** within a compound

## General Nomenclature

Usual follows order **prefix + root + suffix**

| | |
|---|---|
| **Prefix** | Indicates *name/multiplying prefixes/position of branches* |
| **Root** | Indicates *number of carbons in the parent chain* |
| **Suffix** | Indicates the parent chain's *functional group* |

## Root Name/Branch Prefixes

| Number of C atoms / branches | Root prefix | Multiplying prefix |
|---|---|---|
| 1 | *meth-* | *mono-* |
| 2 | *eth-* | *di-* |
| 3 | *prop-* | *tri-* |
| 4 | *but-* | *tetra-* |
| 5 | *pent-* | *penta-* |
| 6 | *hex-* | *hexa-* |
| 7 | *hep-* | *hepta-* |
| 8 | *oct-* | *octa-* |

## Root Name/Branch Prefixes (cont)

| | | |
|---|---|---|
| 9 | *non-* | *nona-* |
| 10 | *dec-* | *deca-* |

**Special nomenclature prefixes:** See *Importance of Functional Groups*, *Haloalkyl/Other Functional Groups*, and *Special Alkyl Branches*

All prefixes are listed in alpha order when writing the name of an organic compound, except for ***cyclo-*** and ***iso-***.

## Importance of Functional Groups

| Functional Group | Suffix if Highest Precedence | Prefix if Lower Precedence |
|---|---|---|
| RC(=O)OH (carboxylic acid) | *-oic acid* [2] | *carboxy-* |
| RC(=O)OR' (ester) | [branch][1]*-yl* [root][1]*-oate* | *alkoxycarbonyl-* |
| RC(=O)ON(-R')R" (amide) | *-amide* | *carbamoyl-* |
| RC≡N (nitrile) | *-nitrile* | *cyano-* |
| RC=O (aldehyde) | *-al* [3] | *oxo-* [3] |
| RC(=O)R' (ketone) | *-one* | *oxo-* |
| R(OH)R' (alcohol) | *-ol* | *hydroxy-* |
| R(N(R')R")-R"' (amine) | *-amine* | *amino-* |
| RC=CR' (alkene) | *-ene* [4] | Always used as a suffix |
| RC≡CR' (alkyne) | *-yne* [4] | Always used as a suffix |

## Importance of Functional Groups (cont)

| | | |
|---|---|---|
| RCCR' (alkane) | *-ane* | Always used as a suffix |
| R(X)R' | Always used as a prefix | See *Haloalkyls/Other Functional Groups* |

[1][branch] and [root] refer to the length of the carbon group's prefix (*meth-*, *eth-*, *prop-*, etc.)
[2]If the carbon in the RCOOH group is not the parent chain, the highest precedence suffix is *-carboxylic acid*
[3]If the carbon in the RCO group is not the parent chain, the highest precedence suffix is *-carbaldehyde*, and the alternate prefix is *formyl-*
[4]If a compound is both an alkene and an alkyne, both *-ene* and *-yne* are used

## Haloalkyls/Other Functional Groups

| Functional Group | Prefix |
|---|---|
| R-O-R' (ether)[1] | [branch]-*oxy-* |
| R-C-R (cycloalkyls) | *cyclo-* |
| R-F | *fluoro-* |
| R-Br | *bromo-* |
| R-Cl | *chloro-* |
| R-I | *iodo-* |
| $R-NO_2$ | *nitro-* |
| 1,2-[branch(es)][2] | *ortho*-[branch(es)] |
| 1,3-[branch(es)][2] | *meta*-[branch(es)] |
| 1,4-[branch(es)][2] | *para*-[branch(es)] |

[1]Ethers take precedence in prefixes over all other prefixes, except the branches attached to the ether group
[2]Applies **only** to benzene ring branches

## Special Alkyl Branches

| Propyl | Butyl |
|---|---|
| n-propyl (normal) | n-butyl (normal) |
| isopropyl (y-shape) | isobutyl (y-shape) |
| | sec-butyl ($2^{nd}$ C) |
| | tert-butyl (t-shape) |

## Alkanes

Contain **only single bonds** between C atoms

| | |
|---|---|
| **General chemical formula** | $C_nH_{2n+2}$ (n = whole number) |
| **Odour** | Odourless |
| **Polarity** | Non-polar (only C-H bonds) |
| **Solubility in water** | Slightly soluble |
| **Boiling/melting point** | Depends on length of parent C chain (more C = ↑ BP, less C = ↓ BP) |

## Alkenes

Contain **at least one double bond** between C atoms

| | |
|---|---|
| **General chemical formula** | $C_nH_{2n}$ (n = whole number) |
| **Odour** | Almost odourless |
| **Polarity** | Non-polar (only C-H bonds) |
| **Solubility in water** | Slightly soluble |
| **Boiling/melting point** | Depends on length of parent C chain (more C = ↑ BP, less C = ↓ BP) |

## Alkynes

Contain **at least one triple bond** between C atoms

| | |
|---|---|
| **General chemical formula** | $C_nH_{2n-2}$ (n = whole number) |
| **Odour** | Almost odourless |
| **Polarity** | Non-polar (only C-H bonds) |
| **Solubility in water** | Slightly soluble |
| **Boiling/melting point** | Depends on length of parent C chain (more C = ↑ BP, less C = ↓ BP) |

## Cycloalkyl

Alkane/alkene/alkyne where the C atoms are joined in a **ring shape**

| | |
|---|---|
| **General chemical formula** | $C_2H_{2n}$ (cycloalkane) $C_2H_{2n-2}$ (cycloalkene) $C_2H_{2n-4}$ (cycloalkyne) *(n = whole number)* |
| **Odour** | Odourless/almost odourless |
| **Polarity** | Non-polar (only C-H bonds) |
| **Solubility in water** | Slightly soluble |
| **Boiling/melting point** | Depends on length of parent C chain (more C = ↑ BP, less C = ↓ BP) |

## Alcohols

Any compound that contains a **hydroxyl (R(-OH)-R') group**

| | |
|---|---|
| **General chemical formula** | $C_nH_{2n-1}OH$ (n = whole number) |
| **Odour** | Slightly pungent |
| **Polarity** | Polar (between O-H bonds); longer C chains decrease in polarity |
| **Solubility in water** | Very soluble; longer C chains decrease solubility |
| **Boiling/melting point** | Depends on length of parent C chain (more C = ↑ BP, less C = ↓ BP) |

## Aldehydes/Ketones

Any compound that contains a **carbonyl (R-C(=O)-R')** group

Aldehydes have the carbonyl group **at the first and/or last C atom** of the molecule

Ketones have the carbonyl group **in the middle C atom(s)** of the molecule

| | |
|---|---|
| **General chemical formula** | $C_nH_{2n}O$ (n = whole number) |
| **Odour** | Pungent (aldehyde) Sweet (ketone) |
| **Polarity** | Polar (between C=O bonds); longer C chains decrease polarity |
| **Solubility in water** | Very soluble; longer C chains decrease solubility |

## Aldehydes/Ketones (cont)

| | |
|---|---|
| **Boiling/melting point** | Very high, increases with length of parent C chain (more C = ↑ BP, less C = ↓ BP) |

## Carboxylic Acids/Esters

Any compound that contains a **carboxyl (R-C(=O)-O-R')** group

Carboxylic acids have the carboxyl group **at the first and/or last C atom** of the molecule

Esters have the carboxyl group **in the middle C atom(s)** of the molecule

| | |
|---|---|
| **General chemical formula** | $C_nH_{2n}COOH$ (n = whole number) |
| **Odour** | Unpleasant (carboxylic acid) Pleasant (ester) |
| **Polarity** | Polar (between C=O bonds); longer C chains decrease polarity |
| **Solubility in water** | Very soluble; longer C chains decrease solubility |
| **Boiling/melting point** | Very high, increases with length of parent C chain (more C = ↑ BP, less C = ↓ BP) |

## Ethers

Any compound that contains an **alkoxy (R-O-R')** group

| | |
|---|---|
| **General chemical formula** | $C_nH_{2n+2}O$ (n = whole number) |
| **Odour** | Slightly pungent |

## Ethers (cont)

| | |
|---|---|
| **Polarity** | Polar (between C-O bonds); longer C chains decrease polarity |
| **Solubility in water** | Very soluble; longer C chains decrease solubility |
| **Boiling/melting point** | Depends on length of parent C chain (more C = ↑ BP, less C = ↓ BP) |

## Amines/Amides

Any compound that contains a **N atom** in a **carboxyl** or **carbonyl** group

Amines have N atoms in a **carbonyl group(s) (R-C(-N(-R')-R")-R"')**

Amides have N atoms in a **carboxyl group(s) (R-C(=O)-N(-R')-R")**

| | |
|---|---|
| **General chemical formula** | $C_nH_{2n-1}NO$ (n = whole number) |
| **Polarity** | Polar (between C=O, C-O and C-N bonds); longer C chains decrease polarity |
| **Solubility in water** | Very soluble; longer C chains decrease solubility |
| **State @ SATP** | Depends on length of parent C chain (more C = more solid, less C = more gas) |

## Intermolecular Forces (IMFs)

Forces that occur **between** molecules

Influence the **physical properties** of a substance

**Weaker** than ***intra*molecular forces** (forces *within* molecules)

**3 main types:**

| | |
|---|---|
| **London Dispersion Forces (LDF)** | **Very weak** forces that **exist in all atoms/molecules** caused by **temporary charges** due to $e^-$ shifts; become **stronger with more $e^-$** |
| **Dipole-Dipole** | Attraction between **opposite charges** of **polar molecules**; main reason for difference in melting/boiling points |
| **Hydrogen bonding** | Strong dipole-dipole forces with **H atoms covalently bonded** with an **N**, **O** or **F** atom |

Strength of forces: (weakest) LDF → Dipole-dipole → H-bonding (strongest)

## Combustion Reactions

**All hydrocarbons** burn with **oxygen gas** (alkanes/alkenes/alkynes/alcohols)

| | |
|---|---|
| **Combustion of hydrocarbon** | $C_xH_y + O_2 \rightarrow CO_2 + H_2O$ |
| **Combustion of alcohol** | $C_xH_yOH + O_2 \rightarrow CO_2 + H_2O$ |

## Elimination Reactions

Take away **2 atoms** to form **double bond** or **H2O**

Also called **condensation/dehydration** reactions

| | |
|---|---|
| **Elimination of haloalkyl** | $C_xH_yX_z$ + [strong base] ➞ $C_xH_{y-1}$ + [halogen (X) salt] + $H_2O$ |
| **Elimination of alcohol** | $C_xH_yOH$ ➞ [conc acid] ➞ $C_xH_{y-1} + H_2O$ |

## Substitution Reactions

**Replace** one atom with another

| | |
|---|---|
| **Substitution reaction** | $C_xH_y + X_2$ ➞[heat/pressure]➞ $C_xH_{y-1}X$ + HX |

**Benzene rings**

Benzene does not have true double bonds, so **only substitution reactions** can be performed

| | |
|---|---|
| **Benzene substitution** | $C_6H_6 + X_2$ ➞ $C_6H_5X$ + HX |
| **Benzene halide substitution** | $C_6H_5X + X_2$➞ $C_6H_4X_2$ + HX |

Halogen in benzene halide reactions forms product **meta position only** (1,3-[X]benzene)

## Addition Reactions

**Add atoms** across double/triple bond

Alkenes/alkynes are **nucleophiles** (they like to give up $e^-$)

| | |
|---|---|
| **Hydrohalogenation** | $C_xH_y$ + HX ➞ $C_xH_{y+1}X$ |
| **Halogenation** | $C_xH_y + X_2$ ➞ $C_xH_yX_2$ |
| **Hydrogenation** | $C_xH_y + H_2$ ➞ $C_xH_{y+2}$ |
| **Hydration** | $C_xH_y + H_2O$ ➞ $C_xH_{y+1}OH$ |

**Markovnikov's Rule: "the rich get richer"**

## Addition Reactions (cont)

The H atom of water/hydrogen gas/hydrogen halide **will always bond** with the C atom that **already had more H atoms** bonded to it in an addition reaction

## Redox Reactions

**Oxidation**

C atoms will form **more bonds to O atoms**

Occurs when an organic compound reacts with an **oxidizing agent** (usually $KMnO_4/K_2Cr_2O_7$)

| | |
|---|---|
| **Oxidation of primary alcohol** | $C_xH_yOH$ ➞[O]➞ $C_xH_{y-1}O$ (**aldehyde**) |
| **Oxidation of secondary alcohol** | $C_xH_yOH$ ➞[O]➞ $C_xH_{y-1}O$ (**ketone**) |
| **Oxidation of tertiary alcohol** | $C_xH_yOH$ ➞[O]➞ **NO RXN** |
| **Oxidation of aldehyde** | $C_xH_yO + H_2O$ ➞[O]➞ $C_xH_{y-1}OH + H_2$ (**carboxylic acid**) |

**Reduction**

C atoms will form **fewer bonds to O atoms**

Occurs when an organic compound reacts with an **reducing agent** (usually $H_2/LiAlH_4$)

| | |
|---|---|
| **Hydrogenation (reduction of aldehyde)** | $C_xH_yO + H_2$ ➞[H]➞ $C_xH_{y+1}OH$ (**primary alcohol**) |
| **Hydrogenation (reduction of ketone)** | $C_xH_yO + H_2$ ➞[H]➞ $C_xH_{y+1}OH$ (**secondary alcohol**) |

## Esterification/Hydrolysis of Esters

**Esterification**

**Condensation reaction** (forms $H_2O$)

Catalyzed by **concentrated $H_2SO_4$** and **high heat**

| | |
|---|---|
| **Esterification** | $C_xH_yCOOH + C_xH_yOH$ ➞[$H_2SO_4$]➞ $C_{2x}H_{2y}CO_2 + H_2O$ |

**Hydrolysis of Esters**

**Reverse reaction** to esterification

*Hydro* = water, *lysis* = break

| | |
|---|---|
| **Hydrolysis of ester** | $C_{2x}H_{2y}CO_2 + H_2O$ ➞ [$H_2SO_4$]➞ $C_xH_yCOOH + C_xH_yOH$ |

**Remember:** Ester is a party girl; she drank some **alcohol** and did some **acid**

## Synthesis/Hydrolysis of Amides

**Synthesis of Amides**

**Condensation reaction** (forms $H_2O$)

| | |
|---|---|
| **Synthesis of amide** | $C_xH_yCOOH$ (carboxylic acid) + $C_xH_yNH_2$ (**amine**) ➞ $C_xH_yONH_2$ (**amide**) + $H_2O$ |

**Hydrolysis of Amides**

**Reverse reaction** to synthesis

| | |
|---|---|
| **Hydrolysis of amide** | $C_xH_yONH_2$ (**amide**) + $H_2O$ ➞ $C_xH_yCOOH$ (carboxylic acid) + $C_xH_yNH_2$ (**amine**) |

## Synthesis of Amines

Amines can be made from **haloalkyls** using **ammonia** as a starting reactant

| | |
|---|---|
| **Synthesis of primary amines** | $C_xH_xX + NH_3$ ➞ $C_xH_yNH_2$ + HX |
| **Synthesis of secondary amines** | $C_xH_xX + C_xH_yNH_2$ ➞ $C_{2x}H_{2y}NH$ + HX |
| **Synthesis of tertiary amines** | $C_xH_xX + C_{2x}H_{2y}NH$ ➞ $C_{3x}H_{3y}N$ + HX |

## Polymers

**Large molecules** that are composed of **many repeated subunits** called **monomers**

Created through **polymerization**

Examples include **plastics**, **DNA**, and **proteins**

Unique physical properties - **checmically unreactive**, **flexible/mouldable/stretchable**

| | |
|---|---|
| **Polymerization** (addition - chain reaction of alkene) | $C_xH_y$ + $C_xH_y$+ $C_xH_y$+ ... ⟶ $[C_xH_y]_n$ |
| **Polymerization** (condensation with alcohol - polyester) | $HOC_xH_yOH$ + $HOOCC_xH_yCOOH$ + ...⟶ $[O_2CC_xH_yO_2C_xH_yO_2]_n$ |
| **Polymerization** (condensation with alcohol - polyamide) | $H_2NC_xH_yNH_2$ + $HOOCC_xH_yCOOH$ + ...⟶ $[NOCC_xH_yO_2C_xH_yON]_n$ |

**Polymerization (condensation)** need the reacting functional group(s) to be on **both sides of the monomer(s)** to be able to complete the chain reaction (**-dioic acid**, **-diol**, **-diamine**)