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 prefix-es/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 *Haloalkyl-s/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-NO2	*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

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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

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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	$C_xH_yOH + O_2 \rightarrow CO_2 + H_2O$

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Elimination Reactions

Take away **2 atoms** to form **double bond** or **H_2O**

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 + $HOOCC_xH_yCOOH$ + ...⟶ $[O_2CC_xH_yO_2CC_xH_yO_2]_n$
Polymerization (condensation with alcohol - polyamide)	$H_2NC_xH_yNH_2$ + $HOOCC_xH_yCOOH$ + ...⟶ $[NOCC_xH_yO_2CC_xH_yON]_n$

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**)

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