

### 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*

### A Root Name/Branch Prefixes

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

### A Root Name/Branch Prefixes (cont)

9	<i>non-</i>	<i>nona-</i>
10	<i>dec-</i>	<i>deca-</i>

**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
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**RC(=O)OH** (carboxylic acid) *-oic acid*<sup>2</sup> *carboxy-*

**RC(=O)OR'** (ester) [branch]<sup>1</sup>-yl [root]<sup>1</sup>-oate *alkoxycarbonyl-*

**RC(=O)ON(-R')R"** (amide) *-amide* *carbamoyl-*

**RC≡N** (nitrile) *-nitrile* *cyano-*

**RC=O** (aldehyde) *-al*<sup>3</sup> *oxo-*<sup>3</sup>

**RC(=O)R'** (ketone) *-one* *oxo-*

**R(OH)R'** (alcohol) *-ol* *hydroxy-*

**R(N(R')R'')-R'''** (amine) *-amine* *amino-*

**RC=CR'** (alkene) *-ene*<sup>4</sup> Always used as a suffix

**RC≡CR'** (alkyne) *-yne*<sup>4</sup> 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*

<sup>[1]</sup>[branch] and [root] refer to the length of the carbon group's prefix (*meth-*, *eth-*, *prop-*, etc.)

<sup>[2]</sup>If the carbon in the RCOOH group is not the parent chain, the highest precedence suffix is *-carboxylic acid*

<sup>[3]</sup>If the carbon in the RCO group is not the parent chain, the highest precedence suffix is *-carbaldehyde*, and the alternate prefix is *formyl-*

<sup>[4]</sup>If a compound is both an alkene and an alkyne, both *-ene* and *-yne* are used

### Haloalkyls/Other Functional Groups

Functional Group	Prefix
<b>R-O-R'</b> (ether) <sup>1</sup>	[branch]-oxy-
<b>R-C-R</b> (cycloalkyls)	<i>cyclo-</i>
<b>R-F</b>	<i>fluoro-</i>
<b>R-Br</b>	<i>bromo-</i>
<b>R-Cl</b>	<i>chloro-</i>
<b>R-I</b>	<i>iodo-</i>
<b>R-NO<sub>2</sub></b>	<i>nitro-</i>
<b>1,2-[branch(es)]<sup>2</sup></b>	<i>ortho</i> -[branch(es)]
<b>1,3-[branch(es)]<sup>2</sup></b>	<i>meta</i> -[branch(es)]
<b>1,4-[branch(es)]<sup>2</sup></b>	<i>para</i> -[branch(es)]

<sup>[1]</sup>Ethers take precedence in prefixes over all other prefixes, except the branches attached to the ether group

<sup>[2]</sup>Applies **only** to benzene ring branches



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### B Special Alkyl Branches

Propyl	Butyl
n-propyl (normal)	n-butyl (normal)
isopropyl (y-shape)	isobutyl (y-shape)
	sec-butyl (2 <sup>nd</sup> 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 =  $\uparrow$  BP, less C =  $\downarrow$  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 =  $\uparrow$  BP, less C =  $\downarrow$  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 =  $\uparrow$  BP, less C =  $\downarrow$  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 =  $\uparrow$  BP, less C =  $\downarrow$  BP)

### Y 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 =  $\uparrow$  BP, less C =  $\downarrow$  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 intramolecular 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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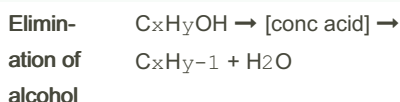
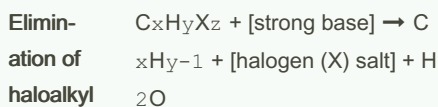
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### ✦ Elimination Reactions

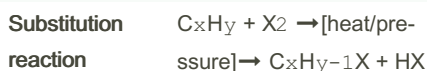
Take away **2 atoms** to form **double bond** or **H<sub>2</sub>O**

Also called **condensation/dehydration** reactions



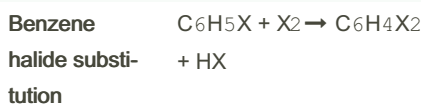
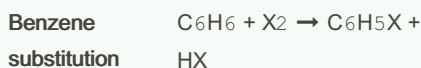
### ↻ Substitution Reactions

Replace one atom with another



#### Benzene rings

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

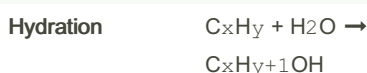
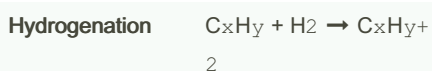
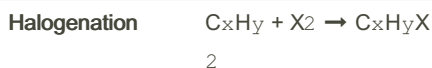
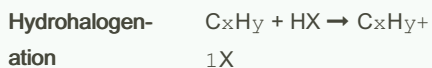


Halogen in benzene halide reactions forms product **meta position only** (1,3-[X]benzene)

### ⊕ Addition Reactions

**Add atoms** across double/triple bond

Alkenes/alkynes are **nucleophiles** (they like to give up e<sup>-</sup>)



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

### ⊕ Addition Reactions (cont)

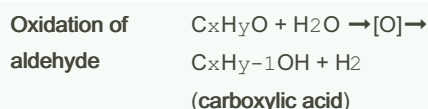
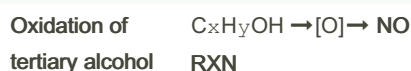
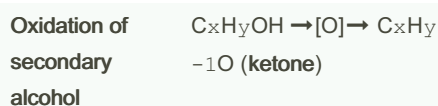
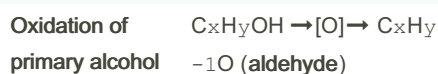
The H atom of water/hydrogen gas/hydrogen halide **will always bond** with the C atom that **already had more H atoms** bonded to it in an addition reaction

### ⚡ Redox Reactions

#### Oxidation

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

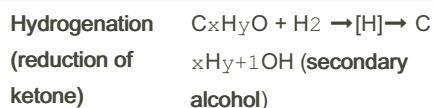
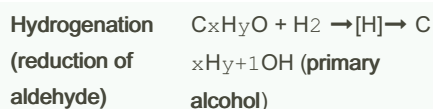
Occurs when an organic compound reacts with an **oxidizing agent** (usually  $KMnO_4/K_2Cr_2O_7$ )



#### Reduction

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

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

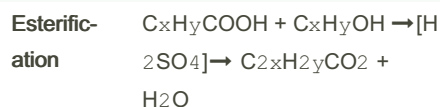


### ↔ Esterification/Hydrolysis of Esters

#### Esterification

**Condensation reaction** (forms H<sub>2</sub>O)

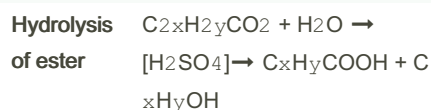
Catalyzed by **concentrated H<sub>2</sub>SO<sub>4</sub>** and **high heat**



#### Hydrolysis of Esters

**Reverse reaction** to esterification

*Hydro* = water, *lysis* = break

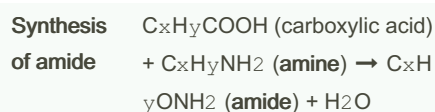


**Remember:** Ester is a party girl; she drank some alcohol and did some acid

### ↔ Synthesis/Hydrolysis of Amides

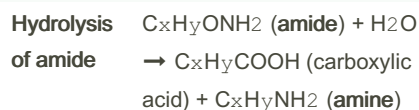
#### Synthesis of Amides

**Condensation reaction** (forms H<sub>2</sub>O)



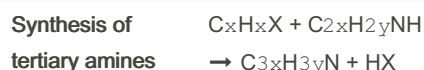
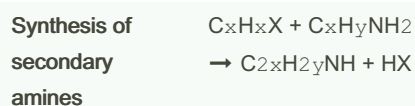
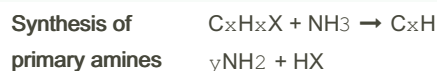
#### Hydrolysis of Amides

**Reverse reaction** to synthesis



### ↔ Synthesis of Amines

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



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### 🔗 Polymers

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

Created through **polymerization**

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

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

**Polymerization** (addition - chain reaction of alkene)  
 $C_xH_y + C_xH_y + C_xH_y + \dots \rightarrow [C_xH_y]_n$

**Polymerization** (condensation with alcohol - polyester)  
 $HOC_xH_yOH + HOOC_xH_yCOOH + \dots \rightarrow [O_2C_xH_yO_2]_n$

**Polymerization** (condensation with alcohol - polyamide)  
 $H_2NC_xH_yNH_2 + HOOC_xH_yCOOH + \dots \rightarrow [NOCC_xH_yO_2C_xH_yON]_n$

**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**)



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