

Organic Chemistry and Fossil Fuels

By far, the longest topic.

Petroleum

Petroleum 石油 is a mixture of hydrocarbons of different lengths. Hydrocarbons are compounds composed of ONLY hydrogen and carbon.

Clicker question: Is ethanol ($\text{CH}_3\text{CH}_2\text{OH}$) a hydrocarbon compound?

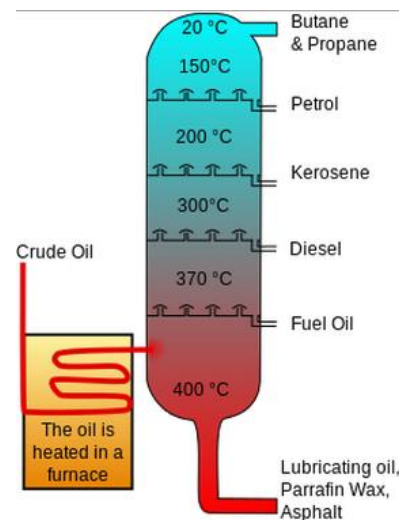
Separation of petroleum

Petroleum is separated by *fractional distillation*.

Since different petroleum fractions have different boiling points, the heavier hydrocarbons with higher boiling points will condense to a liquid at the bottom. Then as the gases flow upwards, shorter hydrocarbons with lower boiling points get condensed as well. The lightest hydrocarbons (methane, ethane, etc.) are collected at the top of the fractioning column. Fractional distillation allows for substances with similar (but different!) boiling points to be separated.

Uses of petroleum

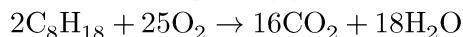
Petroleum is the source of most, if not all carbon compounds, petroleum is important for the organic synthesis of all carbon compounds.



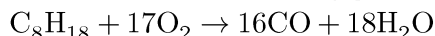
Combustion of carbon compounds

All carbon compounds can undergo combustion, which allows the compound to burn with the presence of oxygen to form carbon dioxide and water. As you may recall from the energy chapter, all combustion processes are exothermic, meaning that they release energy(heat) to the surroundings.

Complete combustion, when there is enough oxygen:



Incomplete combustion, when there is insufficient oxygen:



Possible products of incomplete combustion:

- Water (harmless)
- Carbon monoxide (very toxic and dangerous)
- Unburnt hydrocarbons (also very dangerous)

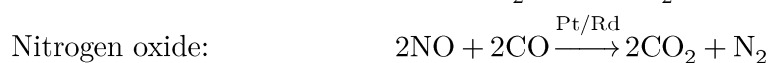
Clearly, we should avoid incomplete combustion. Typically, hydrocarbons with lower carbon content will burn more completely, that is, they are more likely to undergo complete combustion rather than incomplete combustion. A way to evaluate carbon content is to calculate the percentage by mass of carbon in the compound.

e.g. For some C_nH_m

$$\text{Carbon Content} = \frac{12n}{12n + m} \times 100\%$$

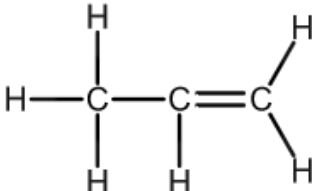
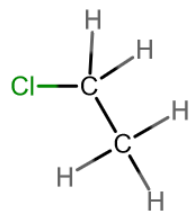
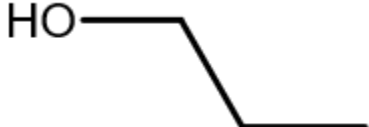
Furthermore, combustion of carbon compounds in internal combustion engine of cars will also produce other pollutants, such as NO, NO₂, which are formed due to the high temperature of the exhaust gas, causing O₂ to react with N₂ to form nitrogen oxides. Another possible pollutant is SO₂, which may be formed due to sulphur impurities in the fuel (though this is more prevalent in coal).

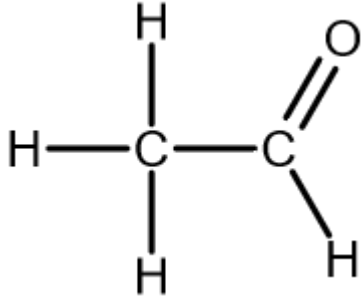
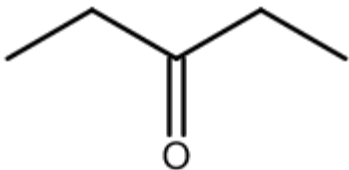
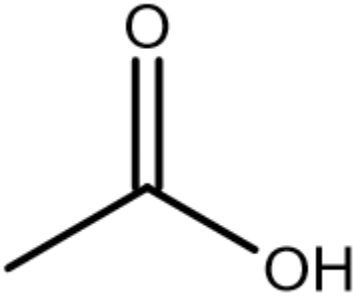
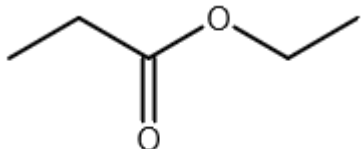
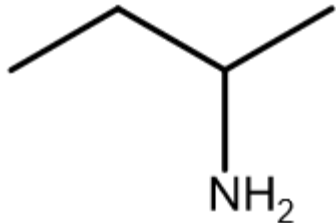
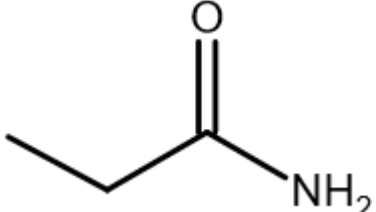
A way to remove these pollutants is by installing a catalytic converter in the exhaust of a car. A catalytic converter contains metals like platinum(Pt) and rhodium(Rd).



Homologous series

Inside a homologous series, members can be represented by a general formula. They have similar chemical properties (as they have the same functional group, more on that later). They also have progressive physical properties. As we progress down a homologous series to its heavier members, the molecules will have a higher boiling point, density and viscosity, can you think of why?

Series name	General Formula	Functional group	Example
Alkanes (no suffix)	$\text{C}_n\text{H}_{2n+2}$	None	$\text{H}_3\text{C}-\text{CH}_3$ Ethane
Alkenes (-ene)	C_nH_{2n} ($n \geq 2$)	C=C bond	 Propene
Haloalkanes (Chloro-/Fluoro-/Bromo-/Iodo-)	$\text{C}_n\text{H}_{2n+1}\text{X}$	Halogen atom	 Chloroethane
Alkanols (-ol)	$\text{C}_n\text{H}_{2n+2}\text{O}$	Hydroxyl group (-OH)	 Propan-1-ol

Alkanals (Aldehydes) (-al)	$C_nH_{2n}O$	Formyl group (-CHO)	 <p>Ethanal</p>
Alkanone (Ketone) (-one)	$C_nH_{2n}O$	Carbonyl group (C=O)	 <p>Pentan-3-one</p>
Alkanoic acids	$C_nH_{2n}O_2$	Carboxyl group (-COOH)	 <p>Ethanoic acid</p>
Ester	$C_nH_{2n}O_2$	Ester group (-COO)	 <p>Ethyl propanoate</p>
(Unsubstituted) Amine	$C_nH_{2n+3}N$	Amino group (-NH ₂) (fun question, how about amino acid?)	 <p>Butan-2-amine</p>
(Unsubstituted) Amide	$C_nH_{2n+1}ON$	Amide group (-CONH ₂)	 <p>Propanamide</p>

Naming of carbon compounds

General steps to follow:

1. Count the length of the **longest** carbon chain **containing all functional groups**
2. Find functional groups and substituents
3. Find the direction of the carbon chain such that the sum of the indexes of the functional groups are the minimum (prioritise suffix functional groups like C=C and -OH over substituents like methyl chain/ethyl chain/halogen atoms)
4. Write out the name, arranging prefixes by alphabetical order of **the group**. For the suffix functional groups, the following order should be followed:
 $\text{-COOH}(\text{-oic acid}) > \text{-COO}(\text{-oate}) > \text{-CONH}_2(\text{-amide}) > \text{-CHO}(\text{-al}) > \text{C=O}(\text{-one}) > \text{-OH}(\text{-ol}) > \text{-NH}_2(\text{-amine})$
5. For alkene groups, replace the -ane part with -ene. E.g. Pentanamide \rightarrow Pent-3-enamide
 Note that the functional groups in the suffix should take priority when it comes to numbering
 (Can you draw the structure of Pent-3-enamide)

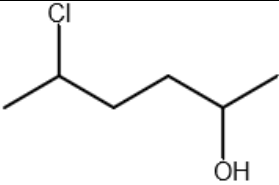
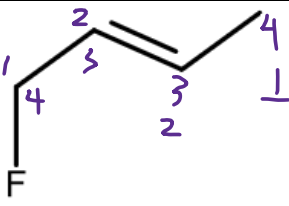
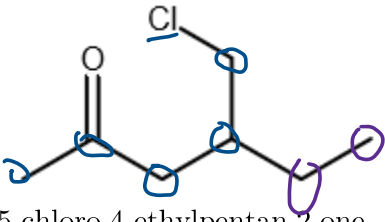
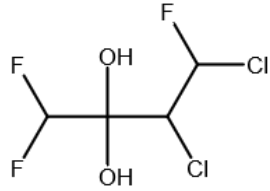
Names of parent chains

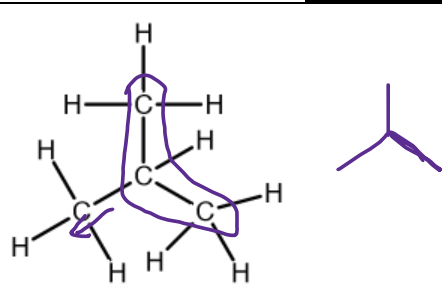
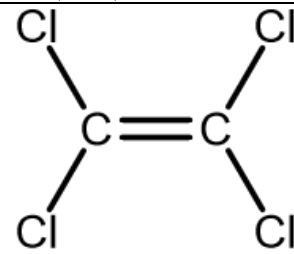
Chain length	Numeric prefix	Chain length	Numeric prefix
1	-Meth	6	-Hex
2	-Eth	7	-Hept
3	-Prop	8	-Oct
4	-But	9	-No
5	-Pent	10	-De

Numeric prefixes for duplicate groups

No of groups		No of groups	
1	(N/A)	4	Tetra-
2	di-	5	Penta-
3	Tri-	6	Hexa-

Naming exercises

 <p>5-chlorohexan-2-ol</p>	 <p>1-fluorobut-2-ene</p>
 <p>5-chloro-4-ethylpentan-2-one</p>	

CH ₂ =CHCH ₂ OH		CH ₃ (CH ₂) ₄ COOH	
 !methylpropane		 !Tetrachloroethene	

Reaction of different functional groups

Alkanes

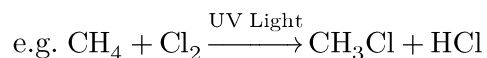
Functional group – None

Combustion of alkanes

Covered before, look back at [Combustion of carbon compounds](#), I just want to remind you that this can happen.

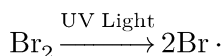
Substitution reaction with halogens

This is a substitution reaction, i.e. parts of the alkane molecule is being *substituted* by another molecule (a halogen in this case).

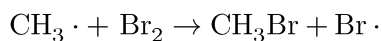
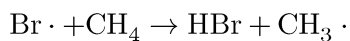


This is a chain reaction caused by *free radicals* formed as UV light breaks down the Cl-Cl bond in Cl₂. Free radicals are chemical species with an ODD number of outermost shell electrons. They are naturally VERY reactive since they do not have an octet structure. The detailed mechanism of this reaction is the only one that you need to actually remember for the exam.

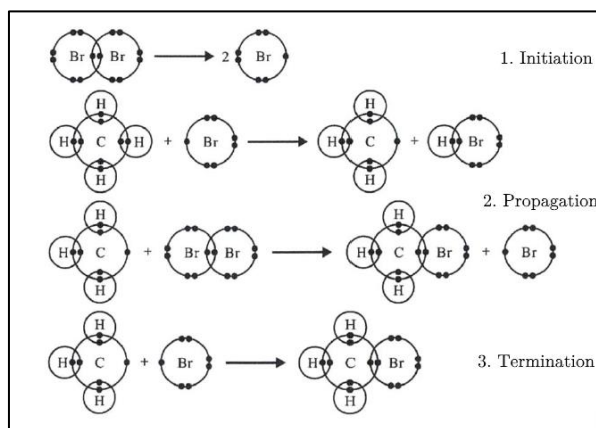
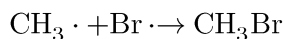
1. Initiation



2. Propagation



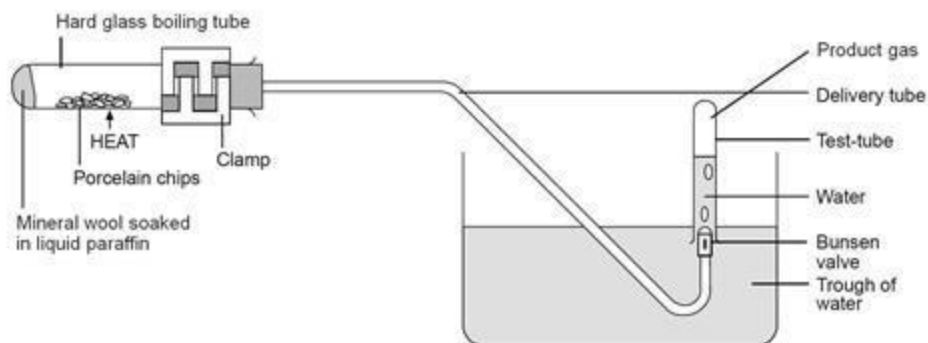
3. Termination



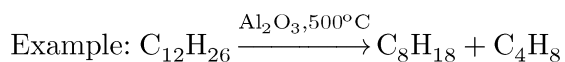
Since substitution can happen multiple times per molecule, it's not a very good way to obtain ONE specific type of haloalkane as many side products will be formed. If methane is in excess, CH₃Br will be the major product. If bromine is in excess, CBr₄ will be the major product.

Cracking reaction

Alkanes can undergo cracking reaction in presence of high temperature, high pressure and a catalyst to be broken down into smaller alkane molecules and alkenes.



Cracking setup

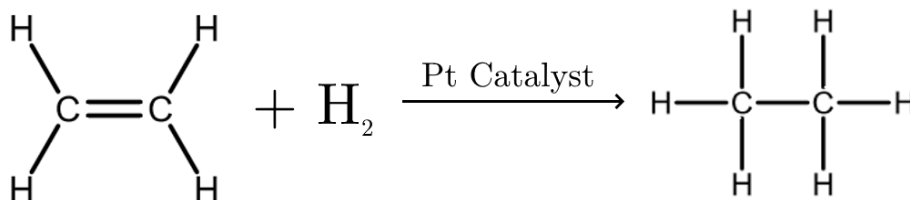


Question: How can we separate the products after cracking? By fractional distillation!

Alkene

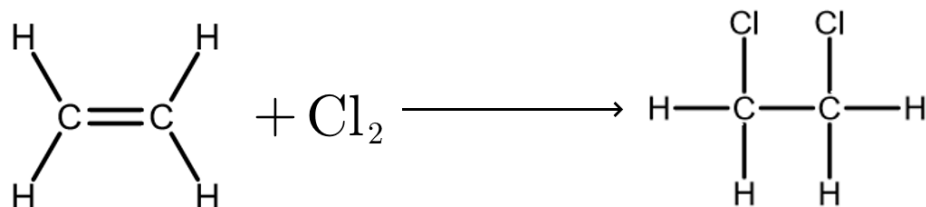
Addition reaction with hydrogen

Also called hydrogenation, this reaction allows alkenes to react with hydrogen, under the presence of a catalyst (Usually Pt) to form an alkane.



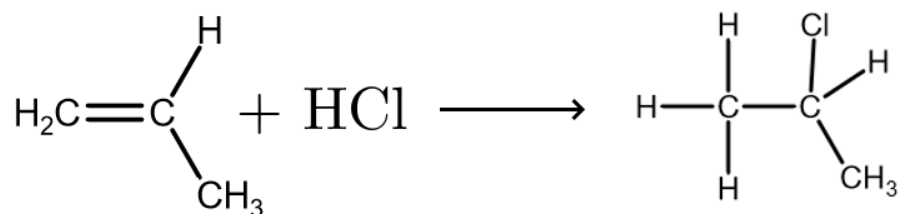
Addition reaction with halogens

Similar to the previous reaction, but with a halogen instead, this reaction does not require any catalysts. This reaction should be remembered well as it is unique to alkenes, meaning that it can be used to differentiate alkenes from other functional groups.

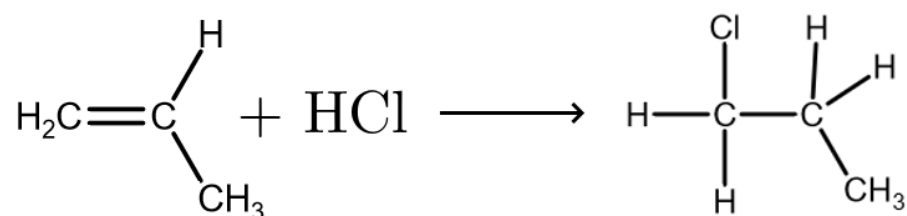


Addition reaction with hydrogenhalides

The same reaction can occur with hydrogenhalides(HX) as well. No catalysts are required.



However, the same reaction can also generate another product, as shown below, 1-chloropropane is formed instead of 2-chloropropane shown above.



We can use Markovnikov's rule to determine the major product:

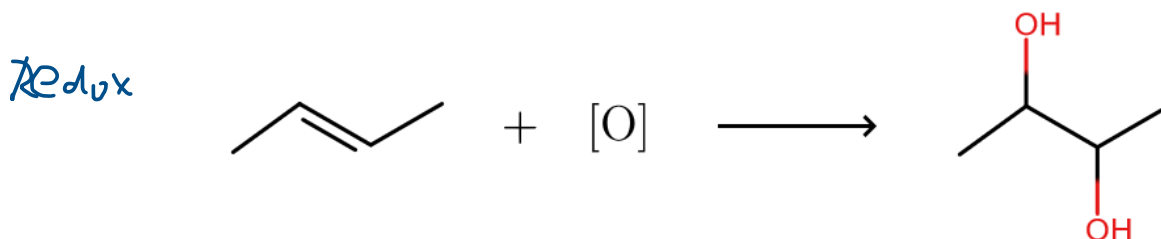
In the addition reaction of hydrogen halide (HX) to the C=C double bond of an alkene, the hydrogen atom in HX is added to the carbon atom with the greater number of hydrogen atoms (while the halogen atom in HX is added to the carbon atom with the smaller number of hydrogen atoms.)

In short, H goes to C atom with more H originally.

Question: Which of the above products is the major product?

Oxidation reaction with potassium permanganate

Alkenes can react with acidified KMnO_4 , which is a strong oxidizing agent to create diol molecules. This reaction is useful to remember since can be used to differentiate alkenes from alkanes. Note that other common oxidizing agents like $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ cannot be used in this reaction since their oxidizing power is not strong enough.



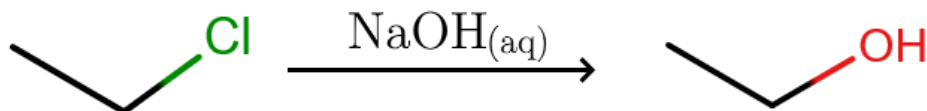
Final note on alkenes:

The double bond in a benzene ring do not resemble the chemical properties of an C=C bond, generally in DSE, you can perceive benzene as having no reactions.

Haloalkanes

Substitution reaction with $\text{NaOH}_{(\text{aq})}$

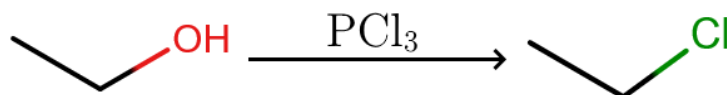
The halogen atom can be substituted for an -OH group instead by reacting it with $\text{NaOH}_{(\text{aq})}$.



Alcohols

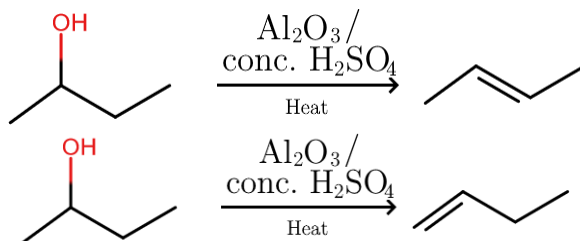
Substitution reaction with HX or PX_3

Alcohols can be converted back into haloalkanes by reacting them with HX (e.g. HCl) or PX_3 (such as PF_3)



Elimination reaction to create alkenes

Alcohols can be turned into alkenes when heated in presence of a catalyst, usually the catalyst is either Al_2O_3 or conc. H_2SO_4 . This reaction **REQUIRES** heat to occur, so do not leave that out.



Again as you can see there are two possible products can be formed in the reaction. The major product of this reaction is the more stable alkene with the more highly substituted double bond. In easier to understand words, the major product will have the C=C bond closer to the center of the molecule rather than to the side.


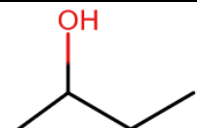

Checkpoint 1

How would you covert the reactants below to the desired product?

1. $\text{CH}_3\text{CHClCH}_3 \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_3$	2. $\text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CH}_2\text{Br}$
3. $\text{CH}_3=\text{CH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{OH}$	4. $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_3$

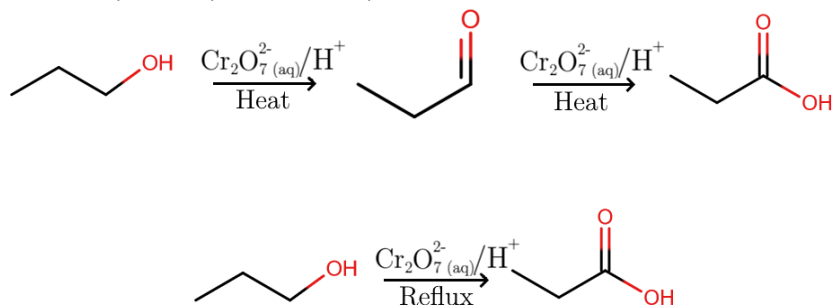
Types of alcohols

Alcohols can be classified into 3 types, primary, secondary and tertiary. You can determine the type of an alcohol by counting how many alkyl groups ($\text{CH}_3\text{CH}_2\ldots$) groups is attached to the carbon atom which is bonded to the $-\text{OH}$ group.

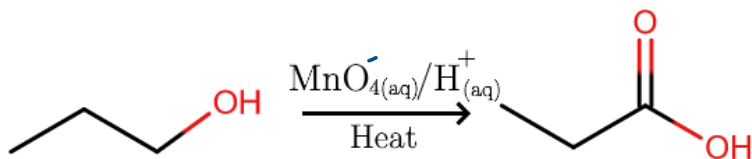
	No. of alkyl groups attached to C atom containing $-\text{OH}$ group	Example
Primary alcohol	0(methanol only) or 1	
Secondary alcohol	2	
Tertiary alcohol	3	

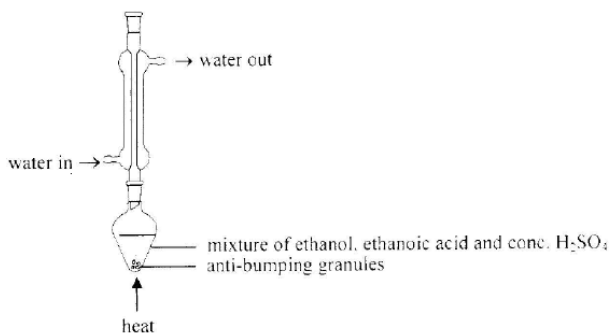
Oxidation of primary alcohols

Primary alcohol can be oxidized by heating with a suitable oxidizing agent, to form aldehydes or carboxylic acids. Usually acidified $\text{Cr}_2\text{O}_7^{2-}$ will be used. Which product will be formed depends on the length of the heating as well as the experimental setup. To get an aldehyde, we want to quickly distill off any products. To get the carboxylic acid, we do not want to distill off products immediately, so a reflux setup is used to condense any aldehyde that may be boiled off and allow it to further undergo oxidation.



If you just wanted to the alcohol directly into a carboxylic acid, then the second equation can be used in order to save space. Alternatively, you can use $\text{MnO}_4^-/\text{H}^+$ as an oxidizing agent, though this will directly convert the alcohol into a carboxylic acid without going through the aldehyde phase.

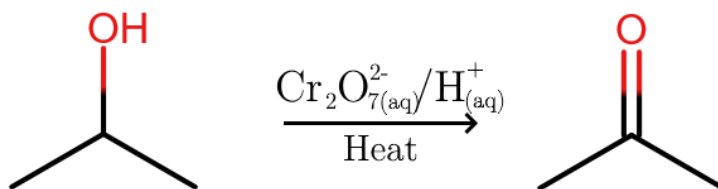




Reflux setup

Oxidation of secondary alcohols

Secondary alcohols can be oxidized to form ketones by heating with an oxidizing agent.



Oxidation of tertiary alcohols

Tertiary alcohols cannot undergo any sort of oxidation, though they can still undergo substitution and elimination reactions in the same manner as above.

Checkpoint 2

A	B	C	D	E

- a) i) Which of the above alcohols can be used for preparing carboxylic acids?
A, B
- ii) Draw the structures of the carboxylic acids formed in part (a)(i)

From A

From B

- b) i) Which of the above alcohols can be used for preparing ketones?
C, D
- ii) Draw the structures of the ketones formed in part (b)(i).

C

D

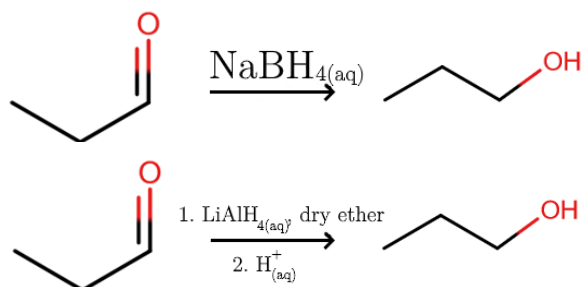
Aldehydes

Oxidation of aldehydes

Aldehydes can be further oxidized to form carboxylic acids by heating with an oxidizing agent, see [Oxidation of primary alcohols](#)

Reduction of aldehydes

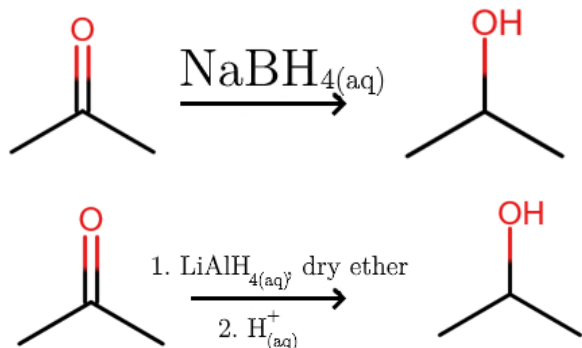
Aldehydes can be reduced back into their primary alcohol forms by reacting with a reducing agent. For aldehydes, both NaBH_4 and LiAlH_4 can be used. Note the order and medium of the reactants used when LiAlH_4 is used as the reducing agent.



Ketones

Reduction of ketones

Like aldehydes, ketones can be reduced back into a secondary alcohol by using NaBH_4 or LiAlH_4 .



Carboxylic acids

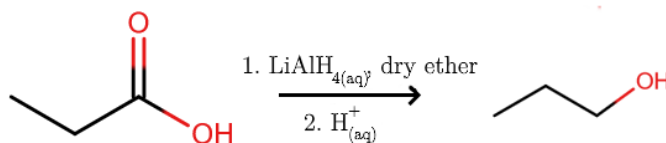
Acid reactions of carboxylic acids

As their name suggests, carboxylic acids are acids, so they can react just like acids.

Reaction with metals	$2\text{RCOOH}_{\text{aq}} + 2\text{Na}_{\text{s}} \rightarrow 2\text{RCOONa}_{\text{aq}} + \text{H}_{2(\text{g})}$
Reaction with alkalis	$\text{RCOOH}_{\text{aq}} + \text{KOH}_{\text{aq}} \rightarrow \text{RCOOK}_{\text{aq}} + \text{H}_2\text{O}_{\text{l}}$
Reaction with carbonates	$2\text{RCOOH}_{\text{aq}} + \text{MgCO}_{3(\text{s})} \rightarrow \text{RCOO}_2\text{Mg}_{\text{aq}} + \text{CO}_{2(\text{g})} + \text{H}_2\text{O}_{\text{l}}$

Reduction of carboxylic acids

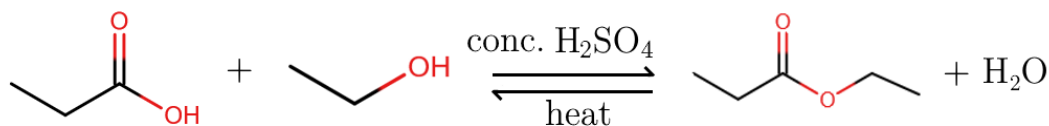
Like aldehydes and ketones, carboxylic acids can be reduced into its primary alcohol form. However, only LiAlH_4 can be used for this because NaBH_4 does not have sufficient reducing power.



Esterification with alcohols

Esters can be created by heating a carboxylic acid together with an alcohol with the presence of conc. H_2SO_4 . Here concentrated sulphuric acid acts as a acid catalyst as well as a dehydrating agent.

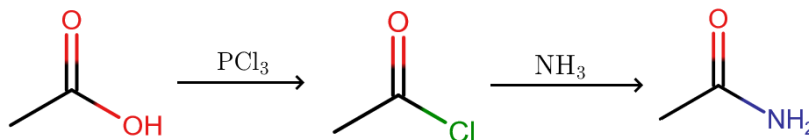
The carboxylic acid molecule will lose its H atom in its COOH group and the O atom, now missing 1 bond will be bonded to the C atom of the alcohol which was originally bonded to the $-\text{OH}$ group in the alcohol. The resulting $-\text{OH}$ and H molecules then combine together to form H_2O . As a result, H_2O is created and the two molecules combine. This process is called condensation reaction as two larger molecules are combined by eliminating a smaller molecule (H_2O in this case).



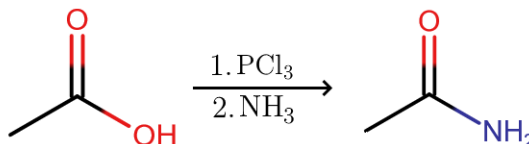
Amide formation

Carboxylic acids can react to form amides by 2 methods.

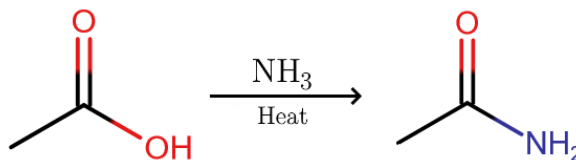
1. Conversion through acid chloride



This process is summarized as:



2. Direct conversion with NH_3 and heating



Checkpoint

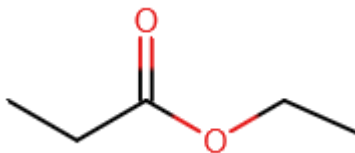
Outline a synthetic route to convert the following reactants to the products.

<ul style="list-style-type: none">Ethanol \rightarrow Ethanoic acid	<ul style="list-style-type: none">Propanone \rightarrow 2-Chloropropane
<ul style="list-style-type: none">HCOOH \rightarrow HCHO	<ul style="list-style-type: none">Ethanal \rightarrow Ethanamide

Esters

Naming of esters

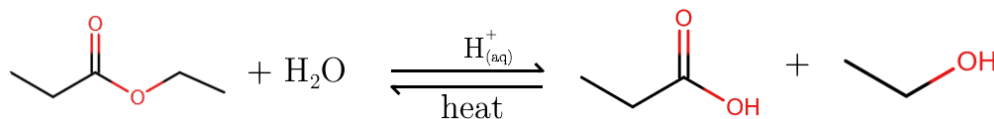
An ester's name typically has 2 words. The first word is derived from the alcohol with a suffix of -yl, while the second comes from the carboxylic acid, with a suffix of -oate.



For example, the compound above is called *ethyl propanoate*.

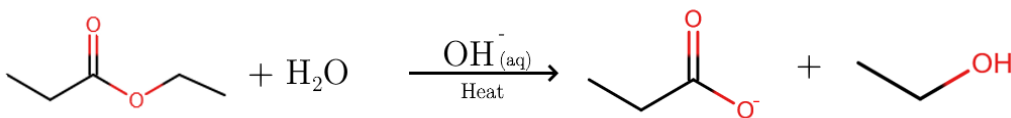
Acid hydrolysis of esters

Esters can be converted back into its constituent carboxylic acid and alcohol by heating it in presence of an acid. The reaction is reversible. Hydrolysis refers to a reaction where a compound is broken down by reaction with water (split by water).

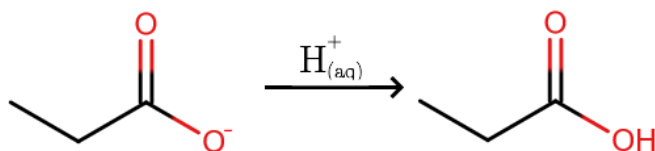


Alkali hydrolysis of ester

The same reaction can be done with an alkali instead of an acid. However, this time the reaction is irreversible. In addition, you get the carboxylate ion instead of the acid.



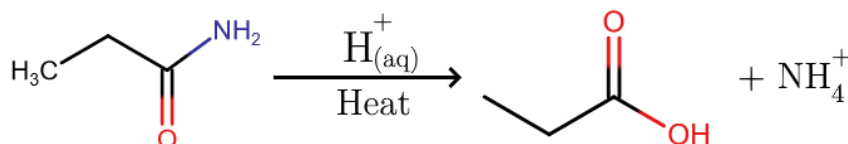
The carboxylic acid can then be recovered by adding an excess amount of dilute acid (e.g. dilute HCl)



Amides

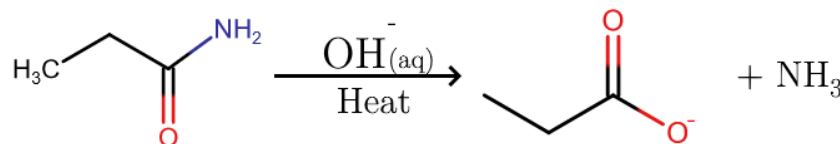
Acid hydrolysis of amides

Amides are formed from the condensation reaction between a carboxylic acid and ammonia. Hydrolysis can be used to reverse the process. Remember that heating is required for hydrolysis and that hydrolysis of amides are irreversible reactions.



Alkaline hydrolysis of amides

The same can be done with an alkaline instead of an acid. A carboxylate salt and ammonia will be formed in this case.



Checkpoint

Two compounds, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ and HCOOH , react in the presence of concentrated sulphuric acid under heating to form an ester.

- Draw the structural formula of the ester and name the ester.

Butyl Methanoate

- What is the use of concentrated sulphuric acid in the reaction?

It acts as an acid catalyst

- c. After the reaction, the ester can be purified by pouring the mixture onto a beaker of water. Explain the principle behind.

The other reactants butan-1-ol, methanoic acid are all miscible with water as they can form hydrogen bonds with water. However, the ester cannot form hydrogen bonds with water, and so it cannot dissolve in water, so it will form an oily layer on top of the water surface while the other reactants dissolve into water. The top layer can be collected as a purified form of the ester.

- d. How can the ester be converted back into the two constituent compounds?

Heat the ester with water and an acid (such as HCl). Hydrolysis reaction will occur and the two constituent compounds will be formed.

Physical properties of functional groups

Functional group	Hydrogen bonds	Hydrogen bonds with water
Alkanes		
Alkenes		
Haloalkanes		Only with F (One way hydrogen bonds)
Alcohols	✓	✓
Ketones		✓ (One way hydrogen bonds)
Aldehydes		✓ (One way hydrogen bonds)
Carboxylic acids	✓	✓
Esters		✓ (One way hydrogen bonds)
Amines	✓	✓
Amides	✓	✓

Functional groups which can form hydrogen bonds with themselves will have a higher boiling point than those that only have van der Waals forces between its molecules.

Functional groups which can form hydrogen bonds with water will be miscible with water. The functional groups which cannot form hydrogen bonds with water are very unlikely to be miscible in water. However, most organic compounds can dissolve in organic solvents, such as dichloromethane.

Isomerism

Isomers are compounds with the same molecular formula but different structures or arrangements of atoms in space. Isomers are typically divided into the following few types:


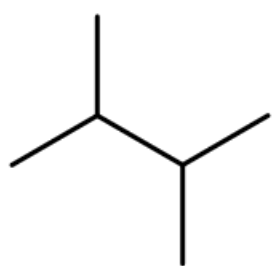
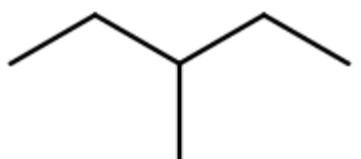
- Chain isomers
- Position isomers
- Functional group isomers
- Cis-trans isomers
- Enantiomers

Structural isomerism

Structural isomers cover three types of isomers: chain, position and functional group isomers.

Chain isomers

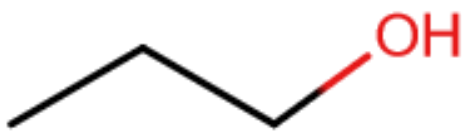
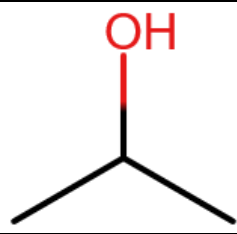
Chain isomers refer to carbon compounds which have the same functional group and molecular formula, but have a different shape in their carbon skeletons.

		
Hexane	1,2-dimethylbutane	3-methylpentane

The above compounds all have the same molecular formula of C_6H_{14} and they are all alkanes. Hence they can be regarded as chain isomers.

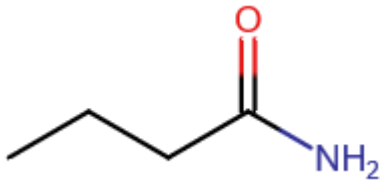
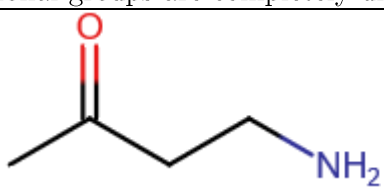
Position isomers

Position isomers refer to molecules with the same functional group and carbon skeleton, but the positions of their functional groups are different.

	
Propan-1-ol	Propan-2-ol

Functional group isomers

These isomers have the same molecular formula, but their functional groups are completely different.

	
butanamide	4-aminobutan-2-one

Here both compounds have the exactly same molecular formula of C_4H_9NO , but the one on the left has an amide functional group while the one on the right has a ketone group and an amino group.

Difference between structural isomers

- Physical properties

Physical properties such as boiling point, polarity, etc. are affected by the geometry of the compound so generally structural isomers have different physical properties.

- Chemical properties

The chemical properties of a carbon compound are purely decided by its functional groups. For chain and position isomers, they have the same functional groups, so their chemical properties are similar. Functional group isomers have different functional groups, so their chemical properties are different.

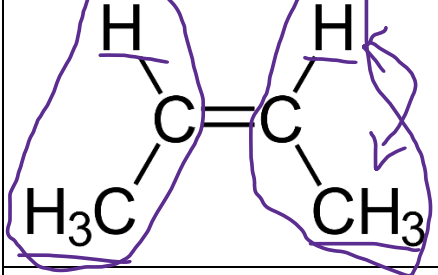
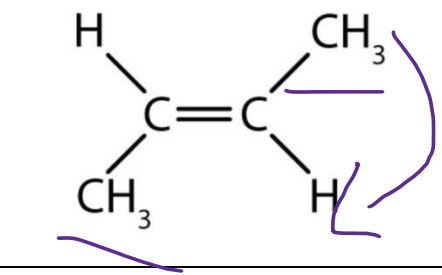
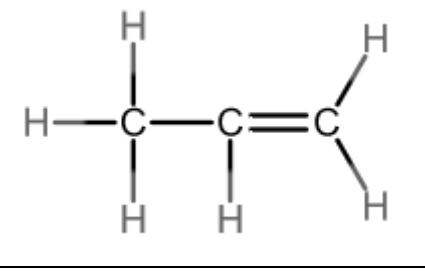
	Chain isomers	Position isomers	Functional group isomers
Carbon skeleton	Different	Same	N/A
Position of functional group	N/A	Different	N/A
Functional group	Same	Same	Different
Physical properties	Different	Different	Different
Chemical properties	Same	Same	Different

Stereoisomerism / Geometrical isomerism

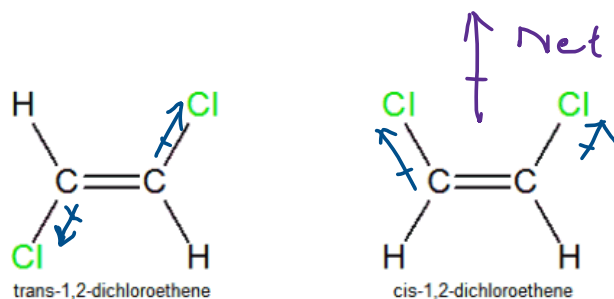
This type of isomerism refers to molecules with identical structures, but their atoms are arranged differently in space.

Cis-trans isomerism

Cis-trans isomers are isomers that have a different arrangement of atoms in space due to the restriction of rotation. Hence, all cis-trans isomerism must have a C=C bond. The easiest way to tell if a molecule has cis-trans isomers or not is by looking at the groups of atoms bonded to the carbon atoms in the C=C bond. If the two groups of atoms are different on BOTH sides of the C=C bond, then cis-trans isomers can exist. If one C atom in the C=C bond is bonded to two SAME groups of atoms (e.g. both are CH₃), then the compound cannot exhibit cis-trans isomerism.

		
<i>Cis-but-2-ene</i>	<i>Trans-but-2-ene</i>	<i>Propene (no cis-trans isomers)</i>

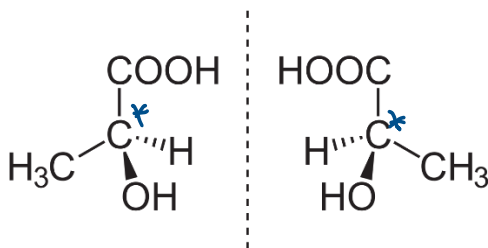
Cis-isomers have the “heavier” group of atoms placed on the same side of the C=C bond while trans-isomers place the “heavier” group of atoms on opposing sides.



Since the bonds of atoms groups are in the same direction for cis-isomers, they tend to be more polar than trans-isomers, resulting in cis-isomers having a slightly higher **boiling point**. However, trans-isomers have a better *packing-efficiency*, which makes trans-isomers have a higher **melting point** than cis-isomers.

Enantiomers

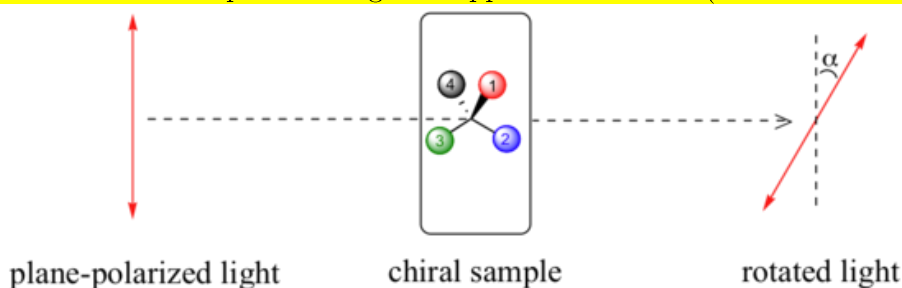
Enantiomers are molecules with the same structure, but their atoms are arranged differently such that one arrangement is the mirrored version of the other. There is no way to rotate the two structures for one to become the other.



The above structures are enantiomers since you cannot rotate the first one to give you a structure identical to the right one. (Look at the H atom, rotation cannot bring it from being to the right of -OH in the left compound, to being on the left of -OH in the second compound)

The easiest way to tell if a compound has enantiomers or not is by finding a *chiral carbon* atom – a carbon atom bonded to 4 distinct groups of other atoms. If it has one, then it should have enantiomers.

Enantiomers have the same structure and functional groups, so they have practically **identical** physical and chemical properties. The only notable difference between the two enantiomers is that they rotate the plane of polarization of a beam of polarized light in opposite directions (but to the same extent).



Polarized light refers to light where the oscillations of the electric and magnetic field occur in one plane only (one for electric and one for magnetic). This, as you may be able to guess from the words “electric and magnetic field” and “oscillation”, involves a lot of physics.

Checkpoint

1. A straight-chain alkanol **P** has a molecular formula $C_4H_{10}O$.
P, when treated with hot concentrated sulphuric acid, gives only two organic compounds **Q** and **R**.
Q exists in form of two geometrical isomers.
Q reacts with hydrogen bromide to form only one organic compound **S**, which is chiral.

a. Draw the structures of **P**, **Q**, **R**, and **S**

P	Q
R	S

b. Draw the three-dimensional diagrams of the geometrical isomers of **Q**.

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c. Draw the three-dimensional diagrams of the optical isomers of **S**.

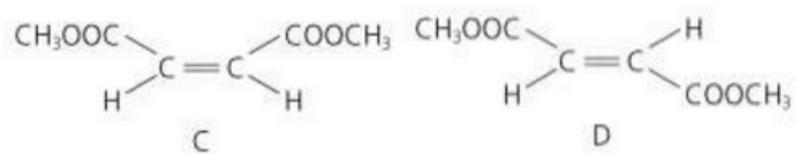
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d. However, when first produced, compound **S** does not show any optical activity. Explain why.

Optical activity – Rotating plane of polarization

Similar amounts of both enantiomers are produced, their rotation effects on the plane of polarization of the beam of light cancel out each other.

2. Consider the following esters C and D.



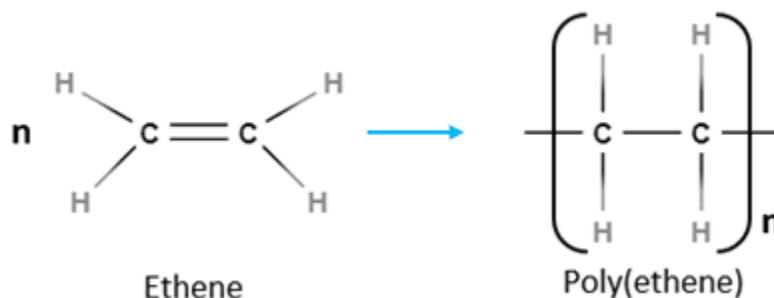
- a. Explain why C has a **higher boiling point** than D.
- b. Explain why D has a **higher melting point** than C.

Polymerization

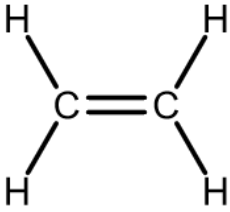
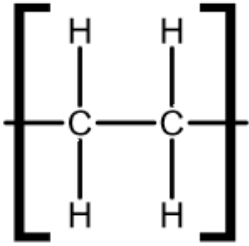
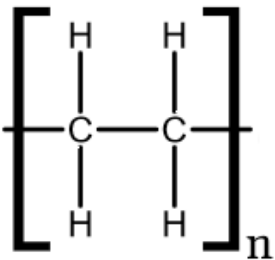
Polymerization refers to turning a lot of small organic compound molecules into one long chain, this process creates plastics, which is probably very useful.

Addition polymerization

Addition polymerization obviously involves addition of molecules together to create one large chain. This is done in high heat and pressure to break down the C=C bonds in alkenes to join them with other alkenes via C-C bonds on both sides, giving us the following polymerization equation.

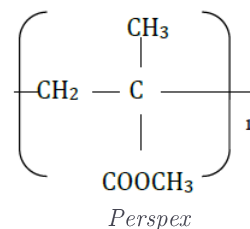


There are a few important terms here to define: (using the above example...)

		
Monomer The base compound used	Repeating unit The repeating part of the final polymer	Polymer Your final long chain product

There are a few common monomers that are used for addition polymerization, try to write their polymerization equations as an exercise.

- Propene → Polypropene (PP)
- Ethene → HDPE / LDPE
- Chloroethene → Polyvinyl Chloride (PVC)
- Tetrafluoroethene → Teflon
- Methyl 2-methylpropenoate (MMA) → Perspex



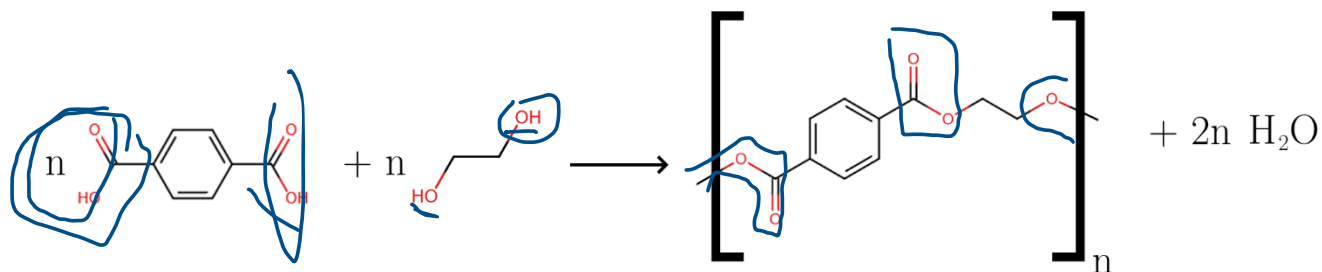
You can find the application for each of the plastics in your textbook.

Condensation polymerization

Condensation polymerization involves joining molecules together by condensation reactions to form long chain molecules. The process will form linkage bonds on BOTH sides of each monomer molecule, this means that monomer molecules need to be bifunctional (have 2 functional groups) to undergo condensation polymerization.

Polyester (PET)

Polyester formation requires two ingredients, a bifunctional alkanedioic acid and a bifunctional alcohol. Typically we choose an alcohol with 2 primary alcohol groups (i.e. -OH groups at the terminal sides of the carbon chain). For example, consider the polymerization between ethanediol and terephthalic acid.



Nylon

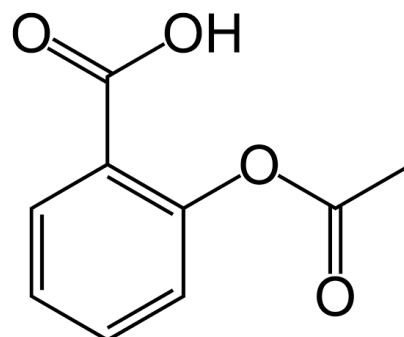
The same process can be done for a di-alkanedioic acid and a diamine molecule. Instead of ester linkages, amide linkages will be formed. Try writing the polymerization equation for the process creating nylon-6,6 from hexane-1,6-diamine and hexanedioic acid. Both nylon and polyester have good tensile strength as they can form hydrogen within their own molecules, making nylon and polyester good choices for fabric and clothing. However, nylon and polyester undergo hydrolysis when in contact with an acid or alkali. Therefore, do not spill drain cleaner on your nylon bag.



Important organic substances

Aspirin

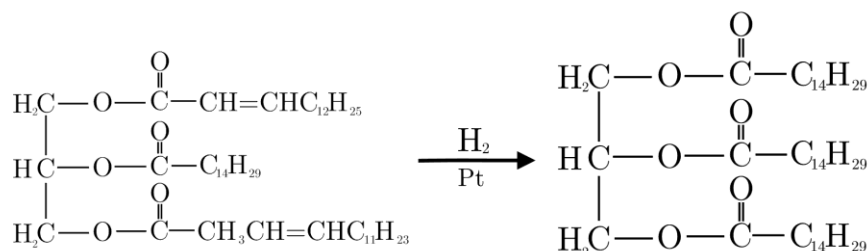
Aspirin, with its chemical name being acetylsalicylic acid, is a common drug. Aspirin can treat mild to moderate pain, inflammation, fevers or arthritis. However, aspirin can come with side effects of indigestion and stomach pain.



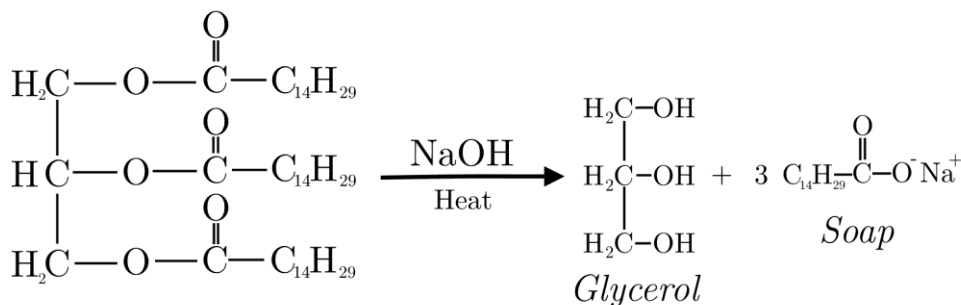
Soaps

Soaps are split into two big types, soapy detergents and soapless detergents. Soapy detergents are usually made from animal fats or other plant products, while soapless detergents are derived from petroleum. Soapy detergents are created from a process called saponification, which turns unsaturated animal fats into soaps.

First we do catalytic hydrogenation to ensure our fat is saturated, i.e. no C=C bond.

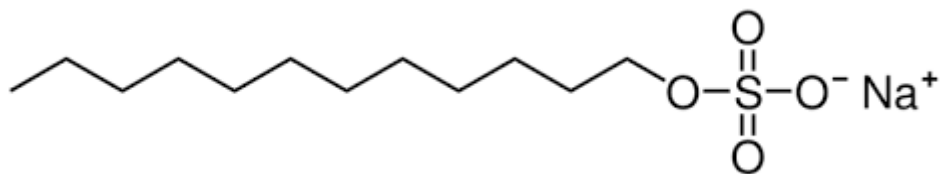


Then we use alkaline hydrolysis to split apart the molecule, glycerol and our soap will be created as products.



The soap will be dissolved in water when it is created. We can extract the soap from the mixture by adding excess $\text{NaCl}_{(\text{aq})}$ to precipitate out the soap since the solubility of soap is worse than NaCl .

Example of soapless detergent:



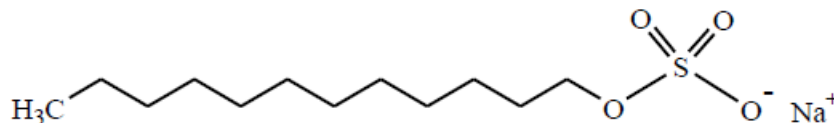
Sodium lauryl sulphate (SLS)

(!) How soaps work:

- Soaps can reduce the surface tension of water so water can spread out and wet surfaces more easily.
- Soaps have an ionic head and a long alkyl chain tail. The ionic head dissolves well in water (hydrophilic) while the long alkyl chain tail dissolves well in oils (hydrophobic).
- When the soap is mixed in with grease, water molecules attract the ionic head, hence lifting up the grease molecule.
- Upon shaking/stirring, the grease molecule breaks into tiny droplets, the droplets cannot come together again due to the repulsive force between the negatively charged ionic heads.

HKDSE 2019 Q15

With reference to the structure of sodium lauryl sulphate (SLS) below, explain why it has cleansing properties. (5 marks)



A

Addition polymerization, 21

C

carbon content, 1
catalytic converter, 2
Chain isomers, 15, 16, 17
chiral carbon, 18
Cis-trans isomers, 16
combustion, 1
condensation, 12
cracking, 6

E

Enantiomers, 16
Esterification, 12

F

fractional distillation, 1
free radicals, 5
Functional group isomers, 15, 16, 17

H

hydrocarbons, 1
Hydrolysis, 13

M

Markovnikov's rule, 7

P

packing-efficiency, 18
Petroleum, 1
Polymerization, 21
Position isomers, 15, 16, 17

R

reflux, 9

S

Structural isomerism, 16
substitution reaction, 5