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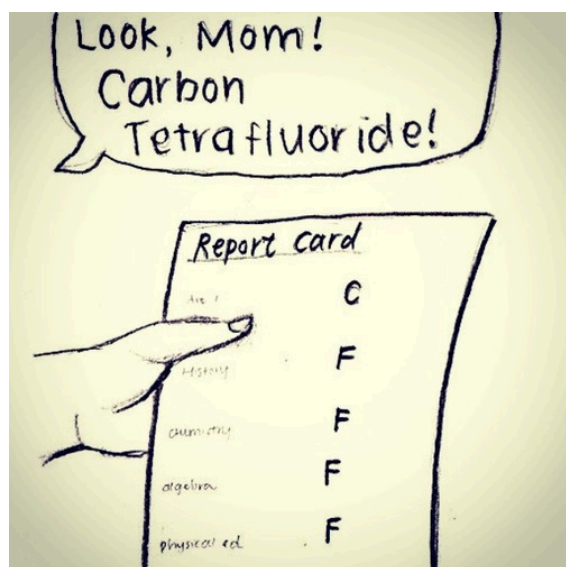
Organic Chemistry

iGCSE / O Levels / Edexcel / AQA

Fahad Hameed Ahmad

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Isomers	10
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Alkenes	17
Alcohols	26
Esters	29
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Scan: free demo class

Organic Compound

→ chemistry of carbon compounds / complex structure
 living organisms, biology, medicine, genetic studies
 petrochemicals, plastic, polymer

Carbon can form 4 strong bonds

Structural formula

arrangement of atoms / bonds

fully displayed: every single atom and bond is shown

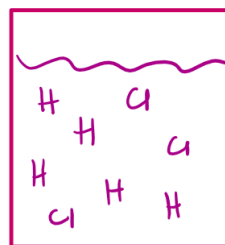
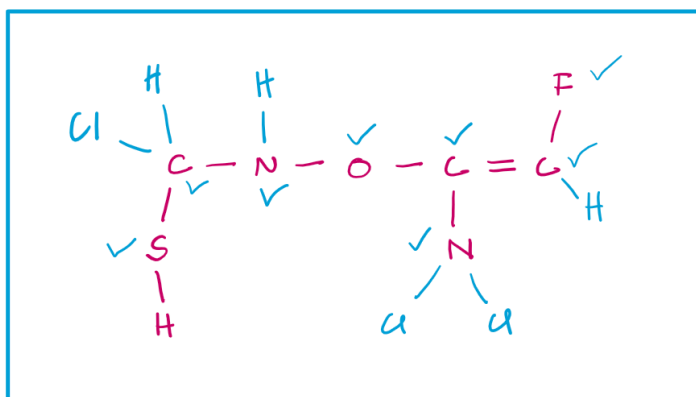
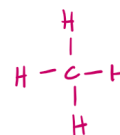
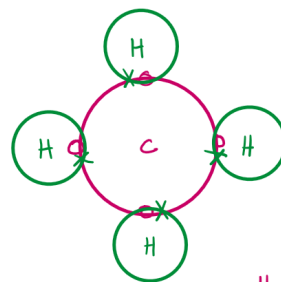
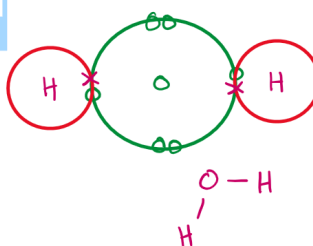
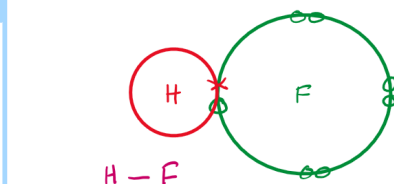
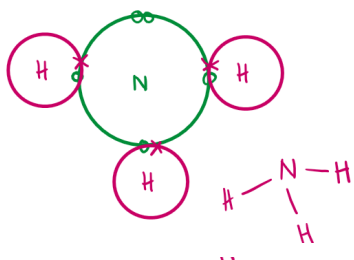
Grp 7 F, Cl, Br, I 1 bond / needs 1e

Grp 6 O, S 2 bonds / needs 2e

Grp 5 N, P 3 bonds / needs 3e

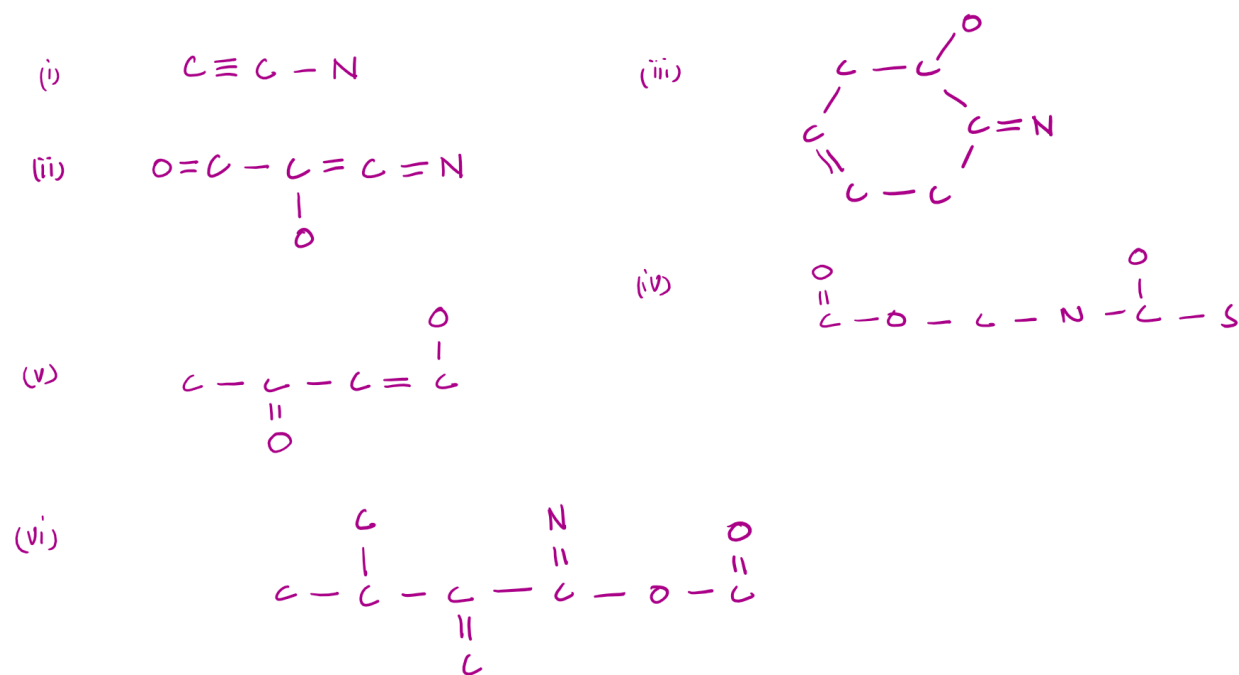
Grp 4 C, Si 4 bonds / needs 4e

H - 1 bond

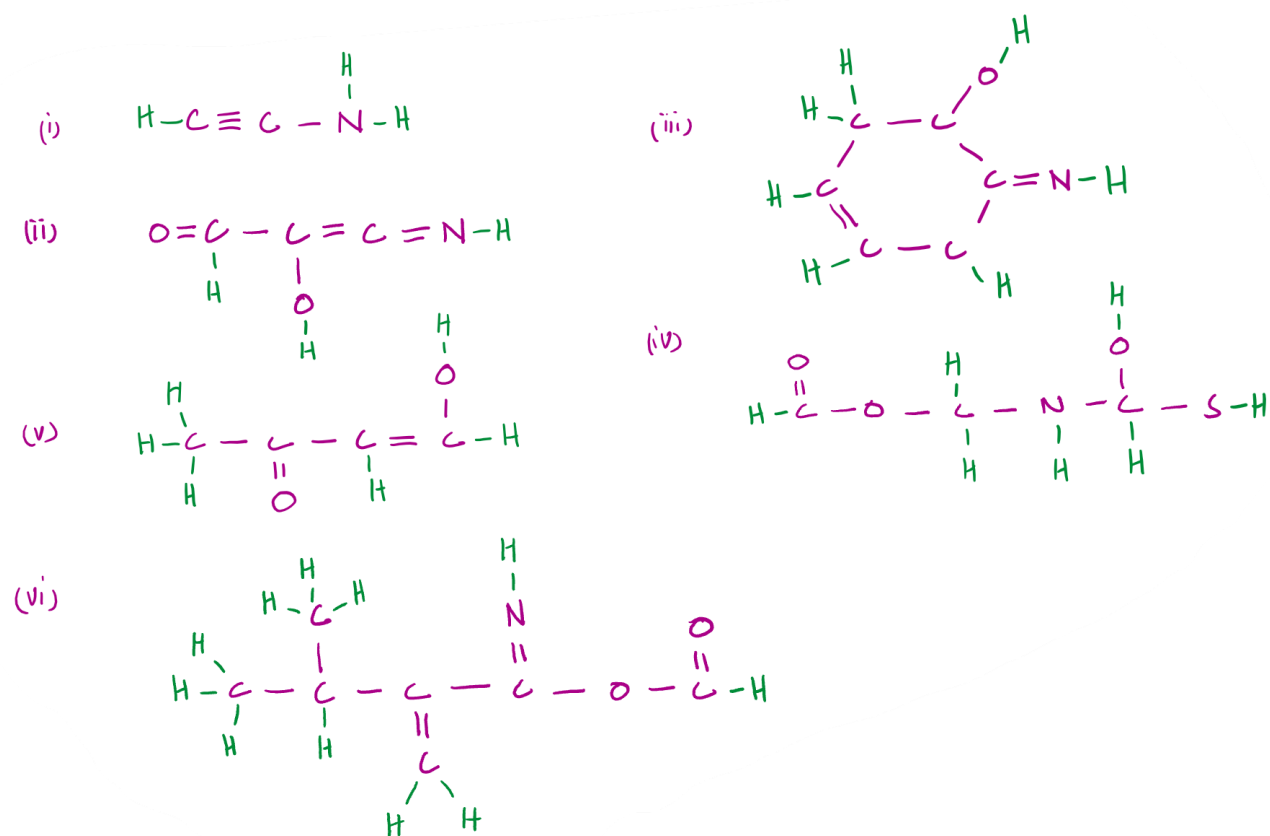


correct structure: fully displayed formula
 (structural formula)

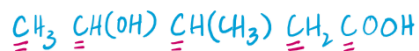
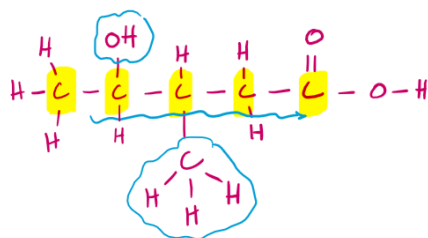
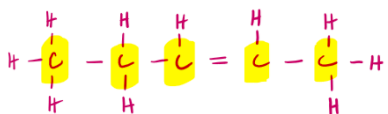
Questions : Complete the Structure by making right number of bonds shown in the table above. Simply add H atoms (or any other atom could also be used)



Answers

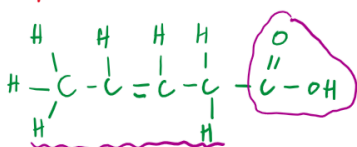


Condensed Structural formula



* branches are put in brackets.

* alkyl group



alkyl chain

$\text{C}_n\text{H}_{2n+1}$ (saturated)

* each $\text{C}=\text{C}$ removes 2H

Homologous Series

family of organic compounds having

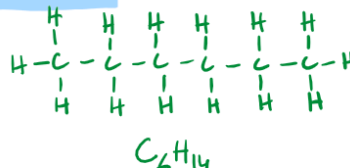
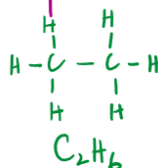
- similar chemical properties (same chemical reactions)
- trends in physical properties (melting, boiling points, viscosity, volatility, electrical conductivity, smell etc)

if size of molecule increases

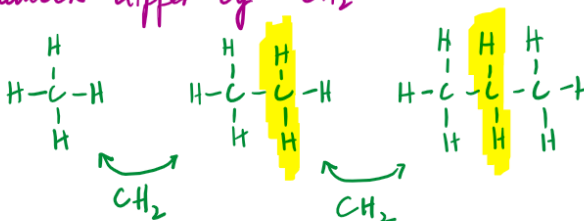
- MP, BP increase
- viscosity increases
- flammability decreases
- solubility in water decreases

- same functional group
group of atoms/structure that determine chemical properties

- same general formula C_nH_{2n+2}



- successive members differ by CH_2



Alkanes C_nH_{2n+2}

saturated hydrocarbons

only single bonds

C, H only

1C meth-

2C eth-

3C prop-

4C but-

5C pent-

6C hex-

hept-

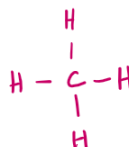
oct-

non-

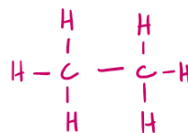
dec-

ane
suffix

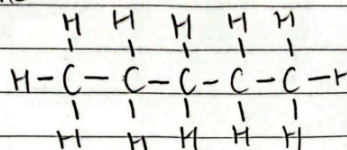
methane

 CH_4

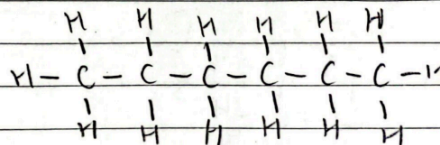
ethane

 CH_3CH_3 C_2H_6

Pentane-

 C_5H_{12} or $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$

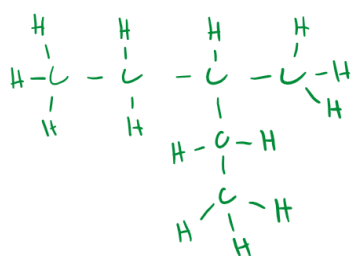
Hexane-

 C_6H_{14} or $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$

*General formula could be used to figure out the formula of the alkane directly.

*Alkanes have a prefix which tells the number of carbon atoms and suffix which is always -ane. So But-ane means, "but" = 4 carbons, "-ane" means alkane.

*naming for branched alkanes is not in course (see below)

branched alkanesnaming not
in course

2 - Alkene C_nH_{2n} suffix -ene

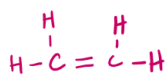
unsaturated hydrocarbon
 ↓
 at least one
 "C=C"

↳ C, H atoms

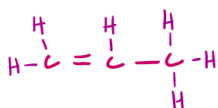
* every C=C, removes 2H atoms

methene - not possible

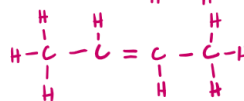
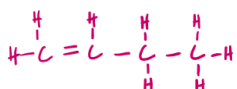
- ethene



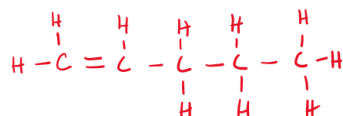
- propene



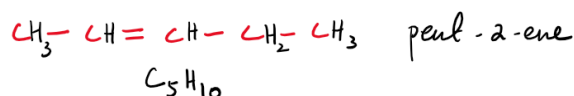
- butene



- pentene



pent-1-ene



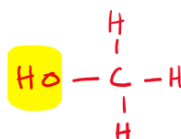
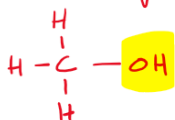
Alkenes are unsaturated hydrocarbons and have at least one C=C

Their suffix is -ene, so But-ene means a 4 carbon atom alkene.

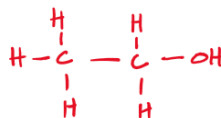
When naming, you have to show where exactly is the C=C located in the chain. Counting is done from the end closest to the C=C. so in pent-2-ene, see above, C=C is located on the second carbon on the chain.

Alcoholshydroxy
functional group $n = \text{no. of C atoms}$

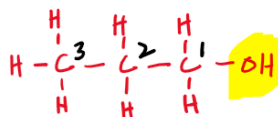
methanol



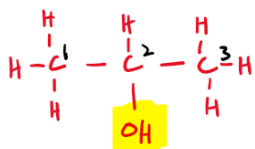
ethanol



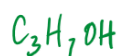
propanol



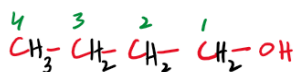
propan-1-ol



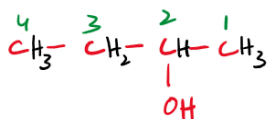
propan-2-ol.



butanol



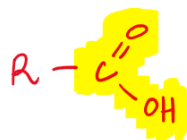
butan-1-ol



butan-2-ol

Alcohols have the -OH functional group which could be attached anywhere in the chain. Naming is done in a similar way. The suffix used is -ol. Naming is done in a similar way. Butan-2-ol means that it's a 4 carbon atom alcohol. You also have to tell the position of the -OH group. See Butan-2-ol above.

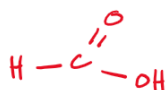
Carboxylic Acids



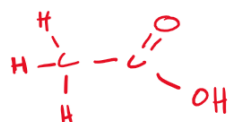
n = One less than Carbon atoms



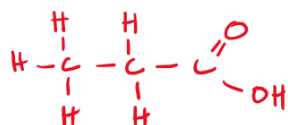
methanoic acid



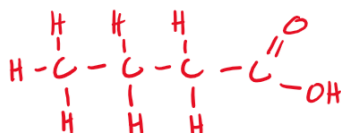
ethanoic acid



propanoic acid



butanoic acid

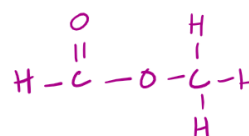
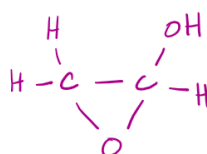
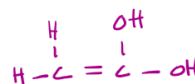
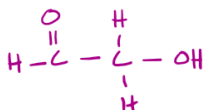
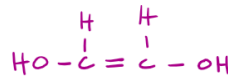
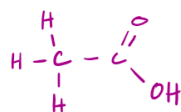


Carboxylic acids have the $-COOH$ functional group highlighted above. The suffix used is $-oic$ acid. So propanoic acid is a 3 carbon atom carboxylic acid.

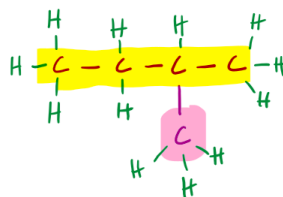
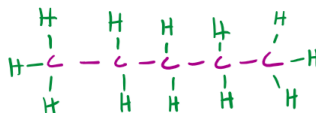
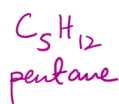
Isomers

Isomers

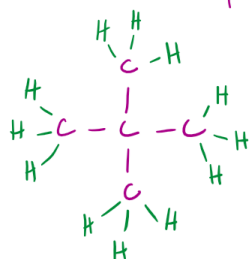
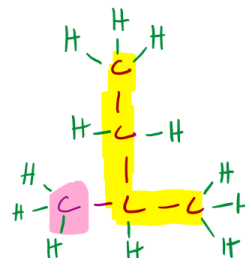
molecules having same molecular formula (same no. of atoms)
but different structural formulas



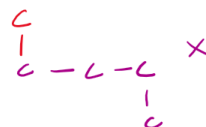
1. chain isomer



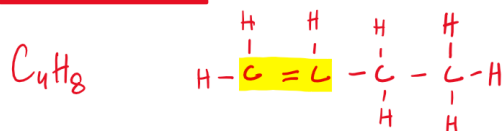
same
not isomer



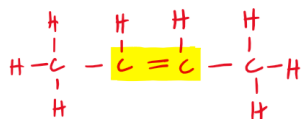
what is not an isomer → flipped, rotated, bent versions
are not isomer



In Chain Isomers, you just change the arrangement of a molecule by changing the carbon-chain.

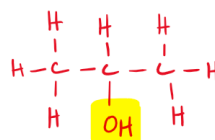
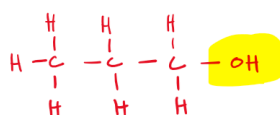
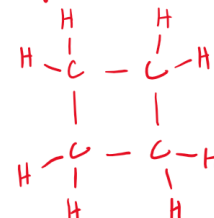
2. positional isomer

but-1-ene

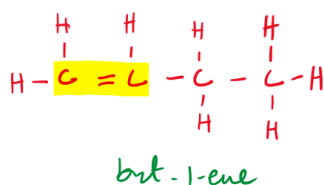


but-2-ene

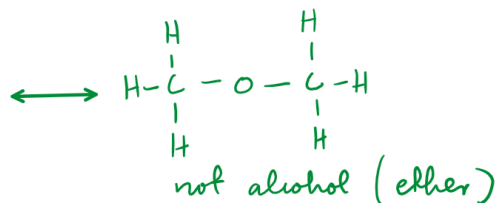
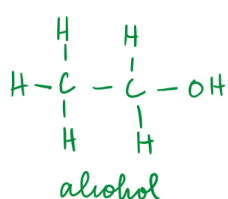
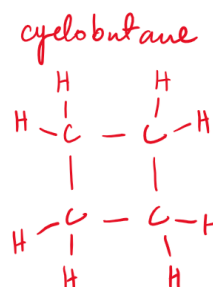
cyclobutane



In Positional Isomers, the position of a certain functional group is changed to make a different arrangement.

3. functional group isomer

isomers



In Functional Group Isomers, the functional group is altered as shown above.

Petroleum / Crude Oil

Petroleum / Crude Oil

entrapped from the earth's crust
living matter (organic) gets compressed over billions of years

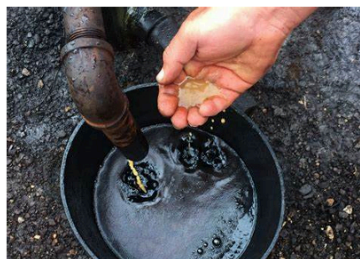
→ mixture of hydrocarbons mostly (alkanes, alkenes)

- small chain hydrocarbons
(methane, propane, butane, octane etc)
- long chain hydrocarbons
(waxes, petroleum jelly etc)

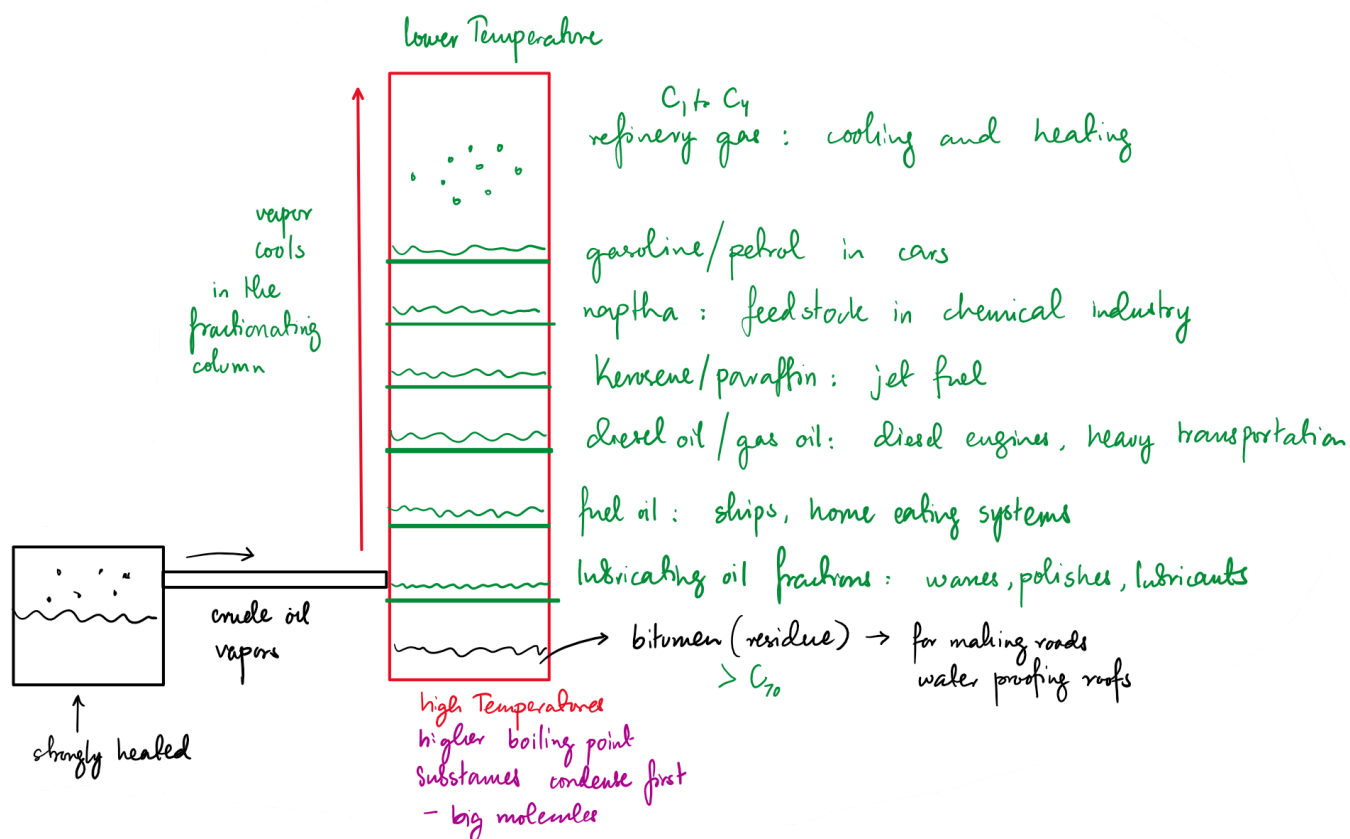
- * as the size of molecule increases
 - melting / boiling point increases
 - viscosity increases
 - flammability decreases ✓

small molecules are more useful and more in demand.

Fractional distillation of Crude Oil / Petroleum



Separation happens via fractional distillation.
Crude oil is heated and vaporized and passed through a fractionating column where it slowly cools. Different crude oil fractions have different boiling points.
higher boiling point fractions condense lower in the fractionating column.
and lower boiling point fractions are obtained at the top



Cracking of long Chain Hydrocarbons

long chain hydrocarbons are not useful

- very viscous, high MP, BP
- not flammable

$T^{\circ}C > 450^{\circ}$

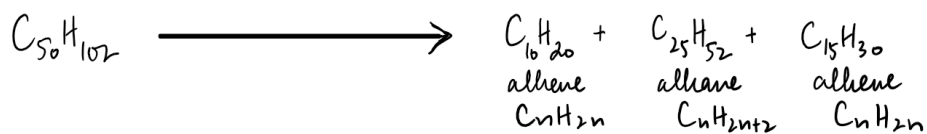
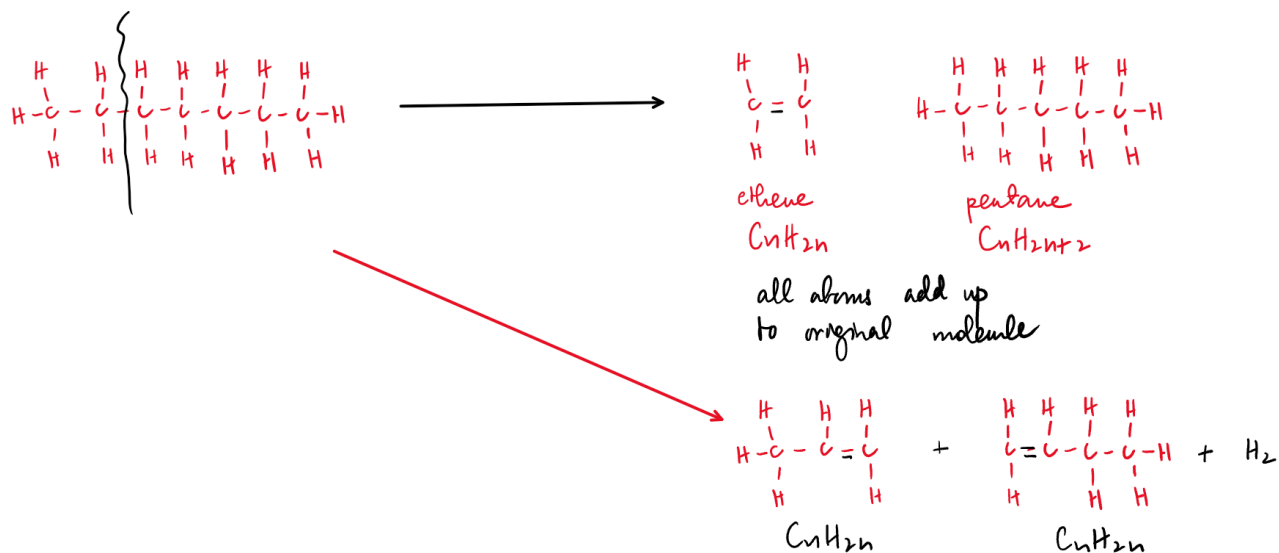
high Pressure

catalyst = Al_2O_3/SiO_2

smaller, more useful hydrocarbons

Alkanes, Alkenes, H_2

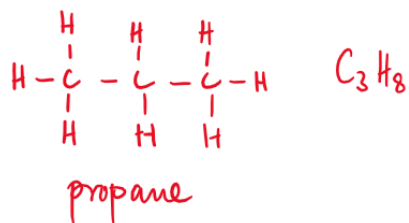
less viscous, low MP/BP
very flammable



Alkanes

ALKANES C_nH_{2n+2}

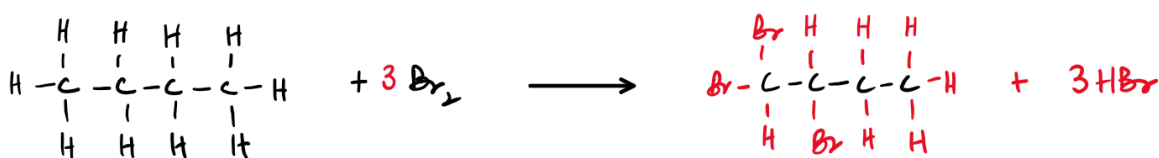
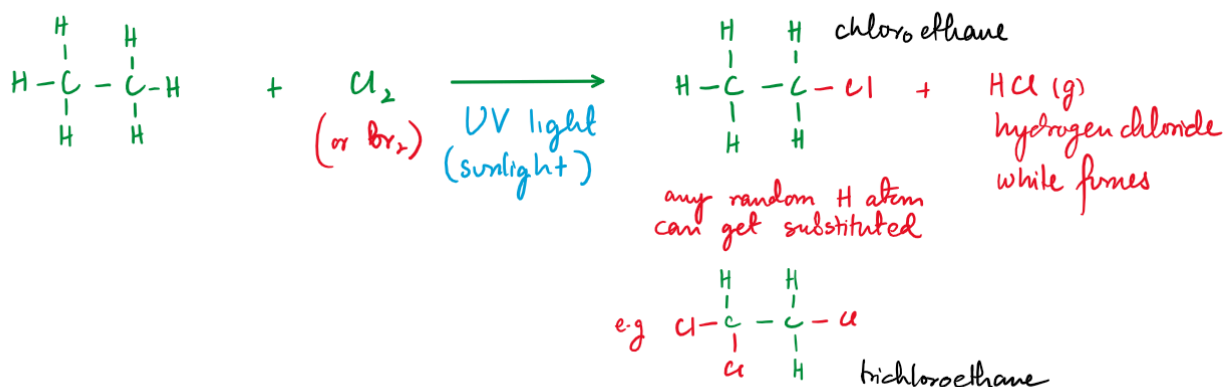
saturated hydrocarbons



Physical Properties

- low MP/BP
- not soluble in water
(mix in organic solvents)
- no electricity conduction

Substitution/Chlorination or Bromination (photochemical reaction)



methane + Cl_2
propane + Cl_2
pentane + Br_2

Home Work

Combustion of Organic Compounds

Combustion (all organic compounds, hydrocarbons burn)



if complete combustion $\rightarrow \text{CO}_2 + \text{H}_2\text{O}$
 exothermic reaction, produces large amount of heat
 * CO_2 is a greenhouse gas, causes global warming
 (glaciers melt, rising sea levels, unpredictable weather)

if incomplete combustion $\rightarrow \text{CO}, \text{C (soot)}$
 $\hookrightarrow$ toxic gas, causes choking / breathing problems

All Organic Compounds undergo similar combustion

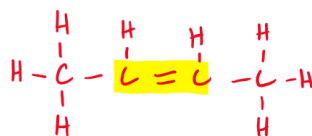


Alkenes

ALKENES



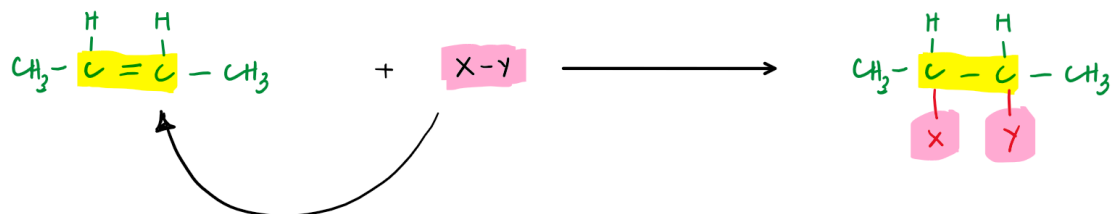
unsaturated hydrocarbons



but-2-ene

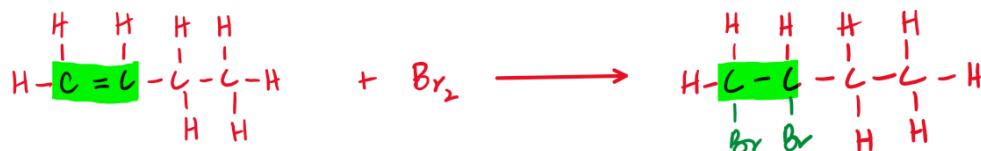
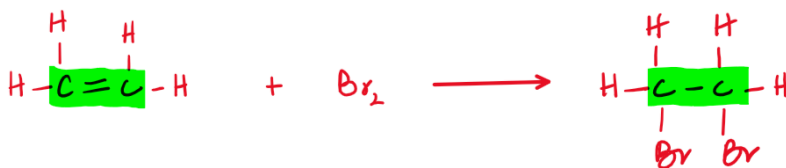
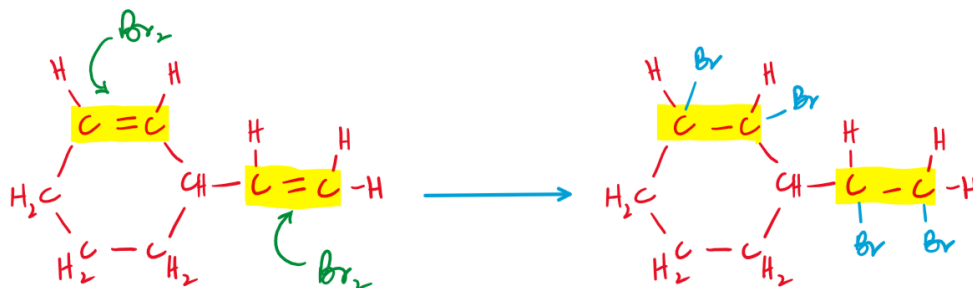
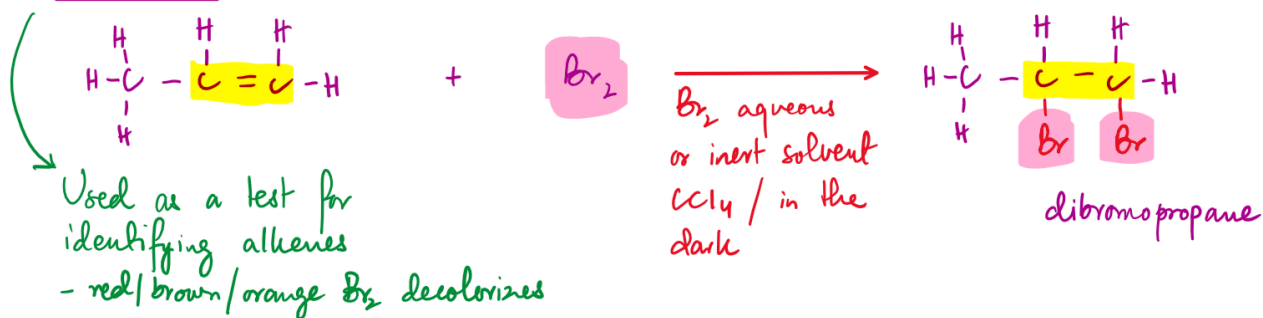
"C=C"
is a reactive functional group

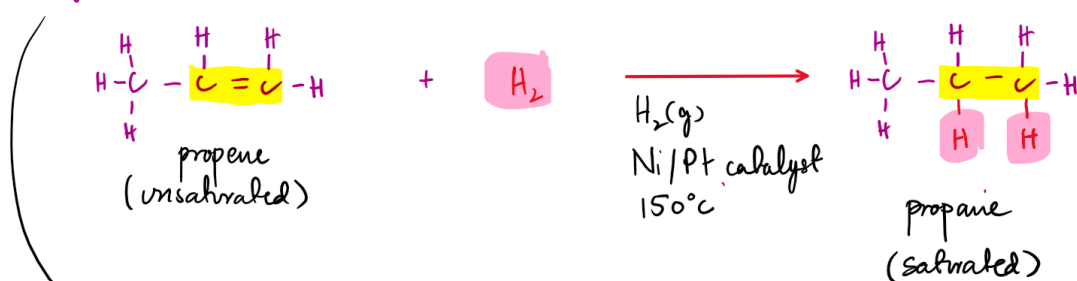
Addition Reaction



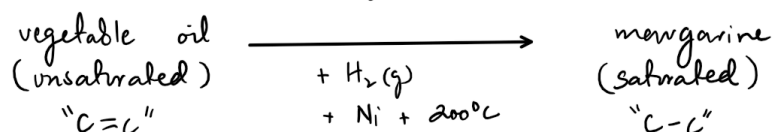
All alkenes undergo addition where a compound/molecule gets added to the double bond.

1- Bromination



2- hydrogenation

used to manufacture margarine



unsaturated oil

low MP/BP / liquid

hydrogen, heat,
nickel catalyst



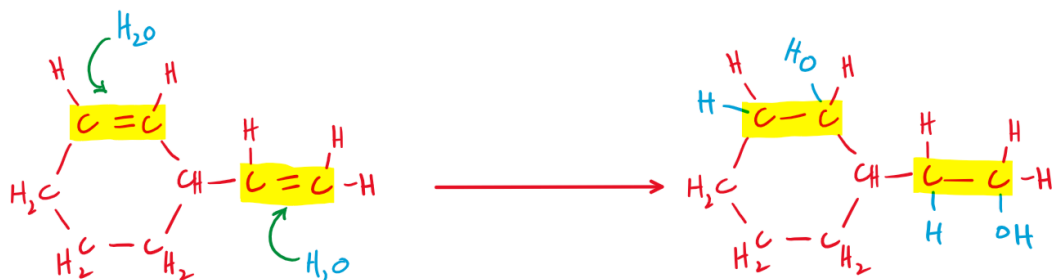
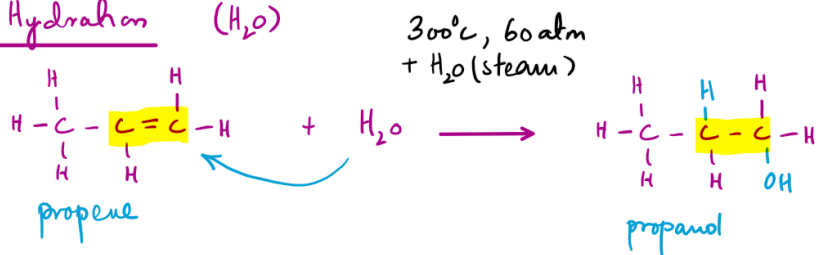
Adding H_2 increases size of molecule

saturated fat

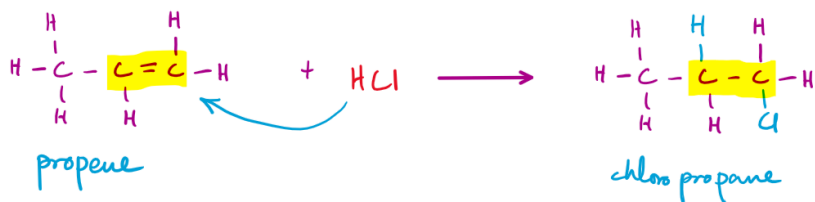
slightly higher MP/BP, more viscous

Complicated molecules of vegetable oil as shown above, H_2 gas molecule gets added to the double bond which increases its size, hence its boiling point increases. This is why margarine is a solid.

3- Hydration (H_2O)

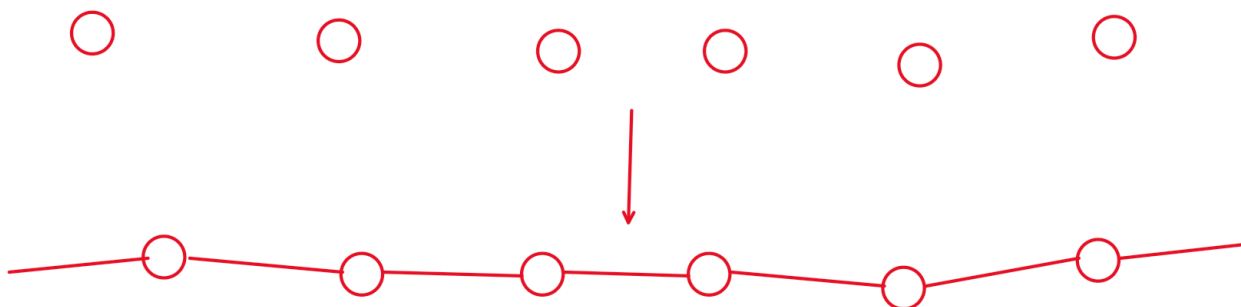


1. Hydrogen halides HCl, HBr, HI

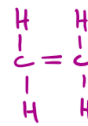
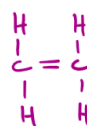
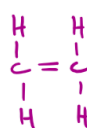
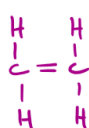
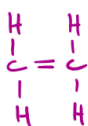
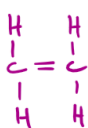
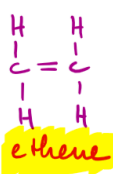


Addition Polymerization $\rightarrow$ only one product / no byproduct

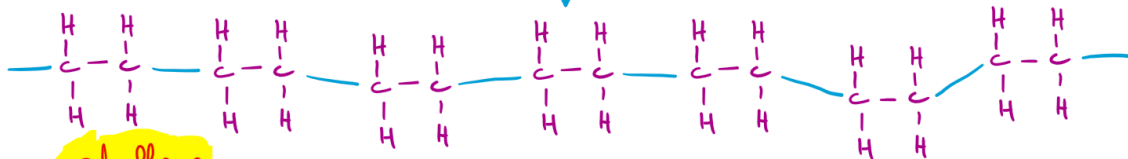
$\rightarrow$ macromolecules formed when many monomers join together



monomer = ALKENE

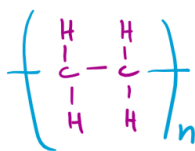


high Pressure / high T^o



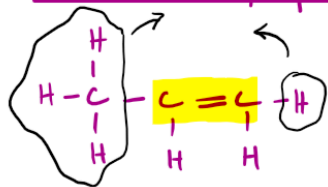
polyethene

$\rightarrow$ plastic bags



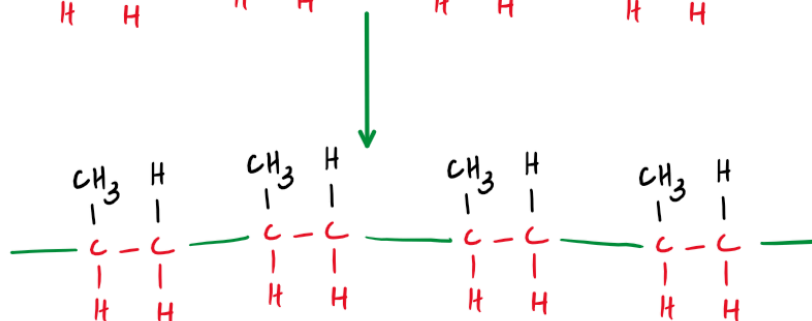
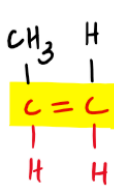
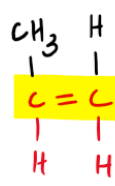
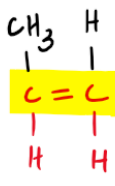
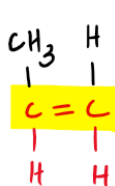
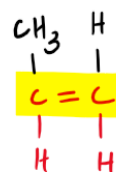
condensed version of polymer, n is no. of times it repeats.

monomer = propene

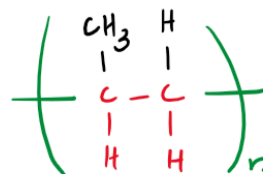


redraw

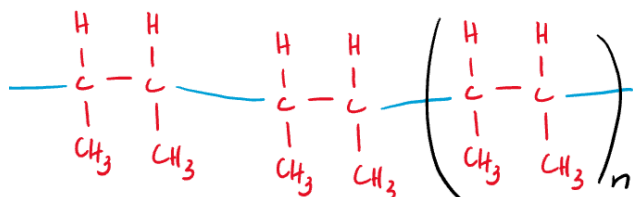
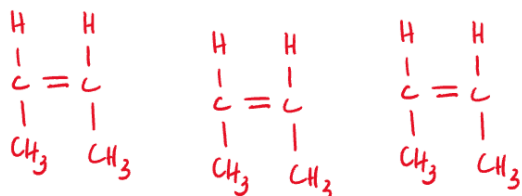
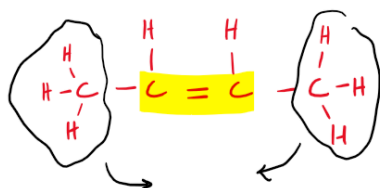
nothing should be on left or right side of $C=C$



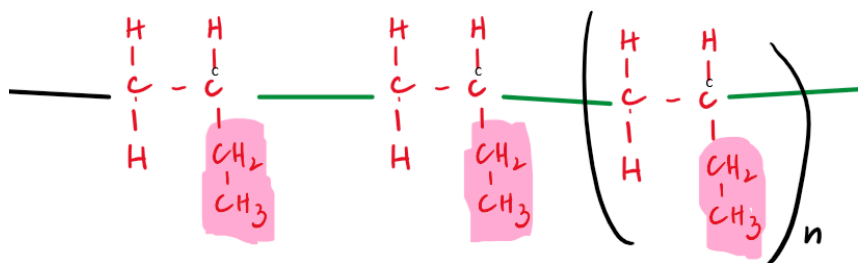
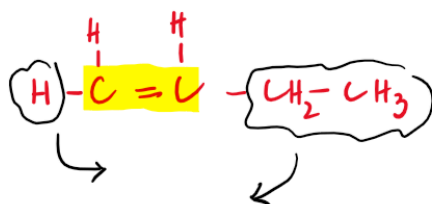
poly propene
plastic bottles



i) but-2-ene

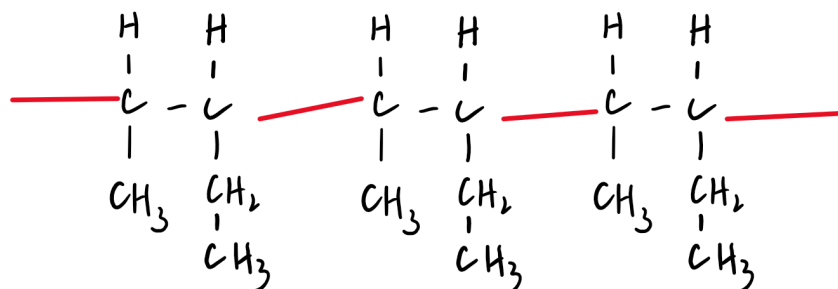
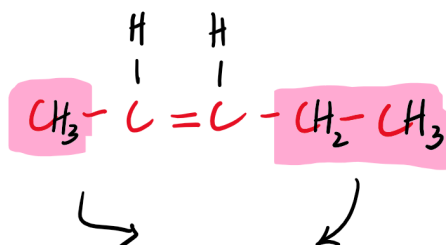


' but-1-ene

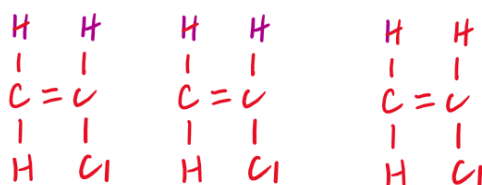
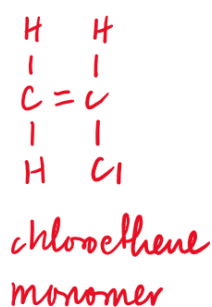


But-1-ene forms poly but-1-ene

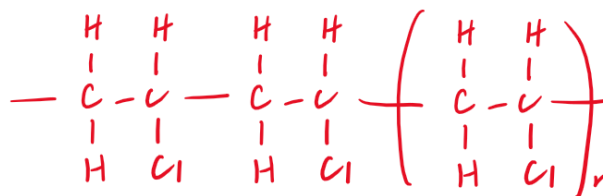
pent-2-ene



Pent-2-ene forms poly pent-2-ene

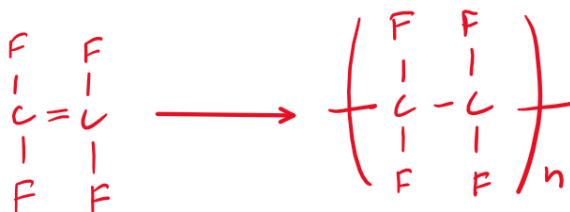
Examples1. PVC polyvinyl chloride

↓ high P, high T



windows, doors, pipes, PVC tiles
light and tough, unreactive

2. Teflon, PTFE Polytetrafluoro ethene



bonds are very strong, very heat resistant
nonstick in cooking utensils.

Harmful effects of Addition Polymers

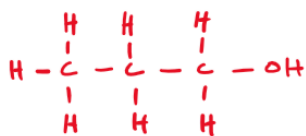
- Addition polymers are very stable, don't decompose naturally, are highly unreactive.
- Nonbiodegradable (takes 100s of years)
- Animals can choke on them

How to get rid of addition polymers

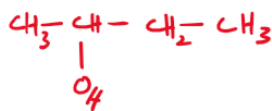
- Landfill sites, land gets wasted as plastics would not decompose naturally
- Recycle (requires effort to sort and collect plastics and sort them)
- Burning produces harmful gases (CO₂ causes global warming, CO causes choking etc)

Alcohols

Alcohols $C_nH_{2n+1}OH$



propan-1-ol

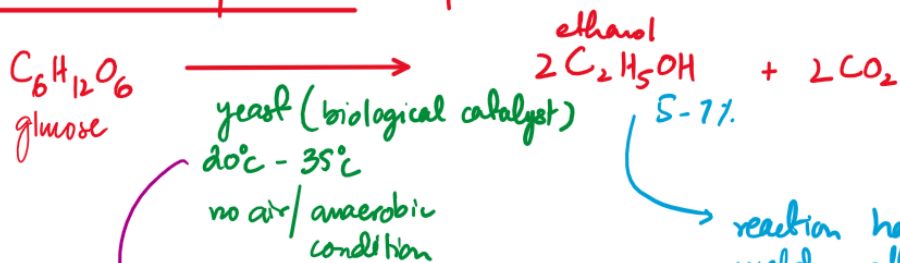


butan-2-ol

Physical Properties

- higher MP / BP (compared to hydrocarbons)
(mostly volatile liquids) → ethanol MP: 78°C
- very soluble in water

How alcohols produced : fermentation



5-7%

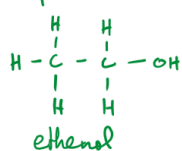
lower T° : yeast is inactive
higher T° : yeast denatures

reaction has very low yield, ethanol will kill the yeast
ethanol produced is distilled

uses : fuel (renewable)
antiseptic / sanitizers
solvent (paints)
medicine (paracetamol)

Oxidation of alcohols

gain of 'O', loss of 'H'



1- O_2 / air

2- Oxidizing Agent

KMnO_4

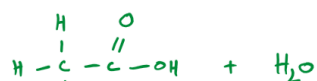
potassium manganate(VII)
(purple to colorless)

or

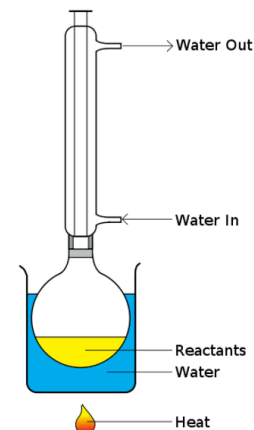
$\text{K}_2\text{Cr}_2\text{O}_7$

potassium dichromate(VI)
(orange to green)

conditions: acidified + reflux / heat

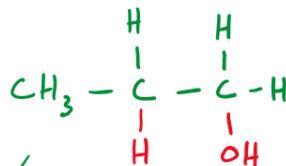
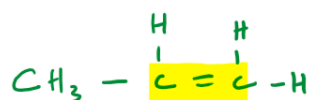


ethanoic acid.
vinegar



Hydration / Dehydration

H_3PO_4 catalyst
 300°C , 60 atm

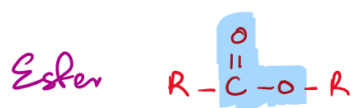


$-\text{H}_2\text{O}$ dehydration

1- $\text{Al}_2\text{O}_3 / \text{SiO}_2$ + heat

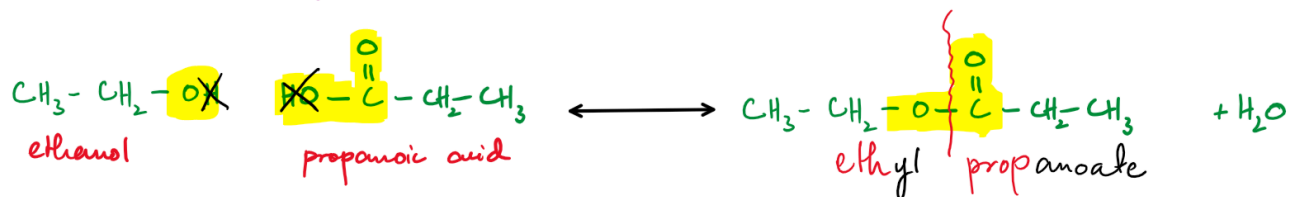
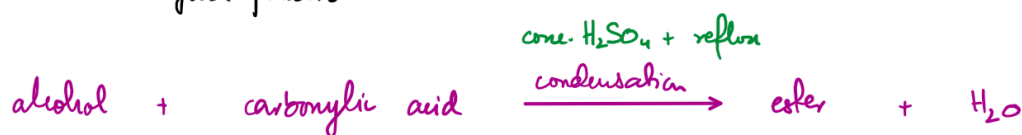
2- concentrated H_2SO_4 / dehydrating agent

Esters

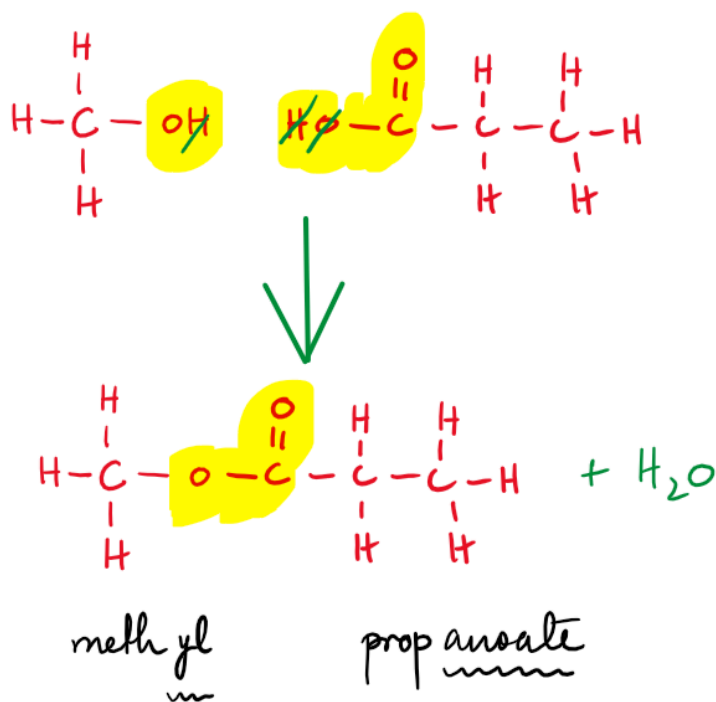


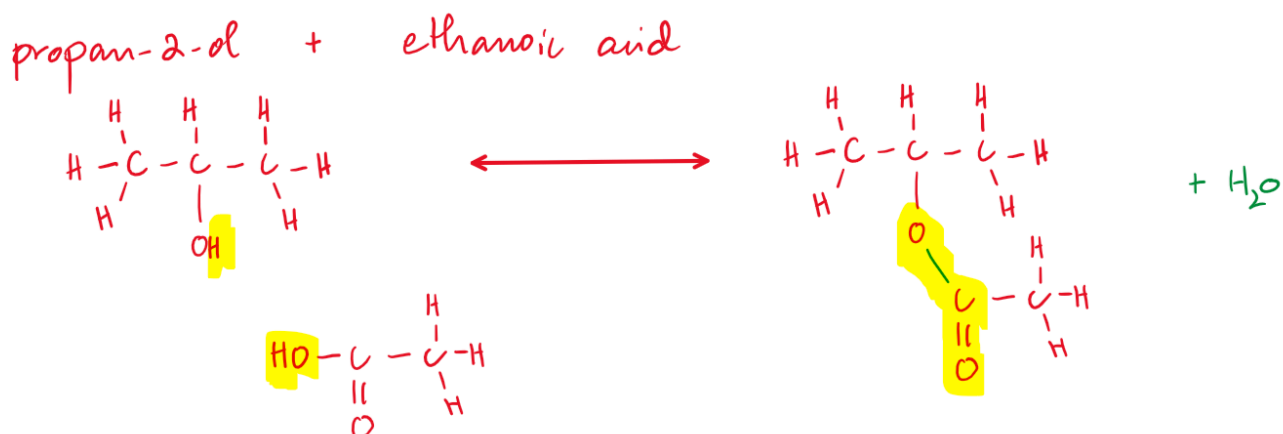
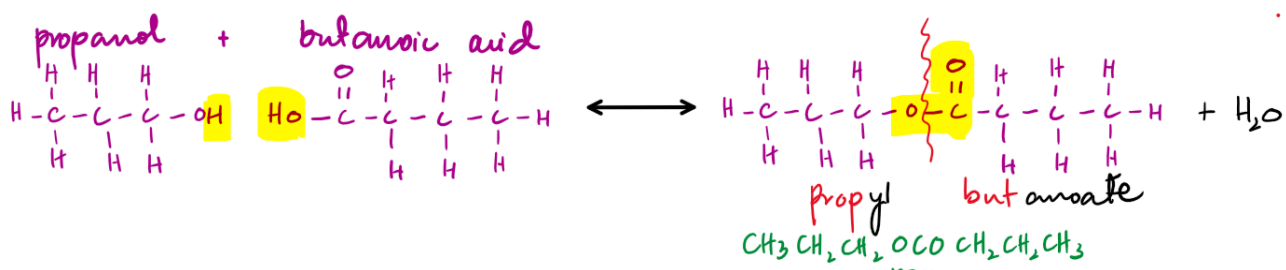
fruity/ sweet smelling oily substances

- perfumes
- food flavours



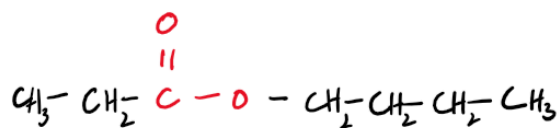
As seen below, alcohol loses H and carboxylic acid loses OH and you therefore get an ester.



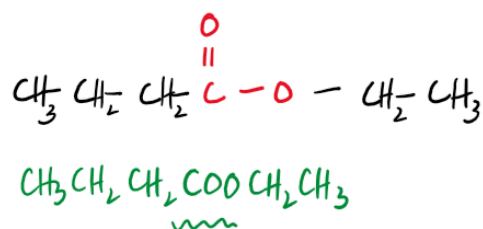


drawing esters directly

butyl propanoate
 4C 3C

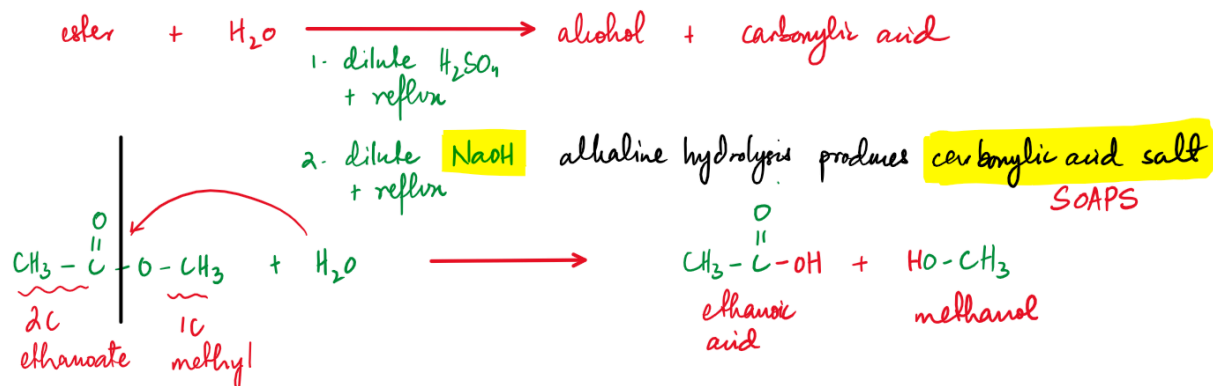


ethyl butanoate
 2C 4C



This is the reverse of ester formation where the ester breaks down

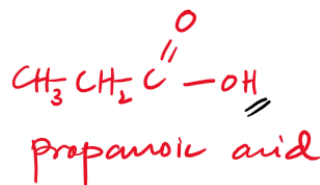
hydrolysis of esters



One thing to note is that if alkali (NaOH) is used for hydrolysis of esters then instead of carboxylic acid RCOOH you get a salt which is RCOO⁻ Na⁺ as the alkali ends up reacting with the acid.

Carboxylic Acid

Carboxylic Acids $C_nH_{2n+1}COOH$



- * high MP / BP compared to alkanes and alkenes (mostly liquids, e.g. vinegar: ethanoic acid)
- * very soluble in water (same as alcohols)

* Carboxylic Acids are Weak Acid

↳ pH = 5 to 6 (universal indicator - orange)
ionize partially when aqueous
produce fewer H^+ ions



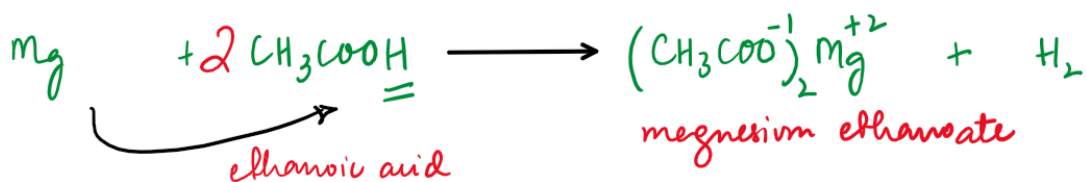
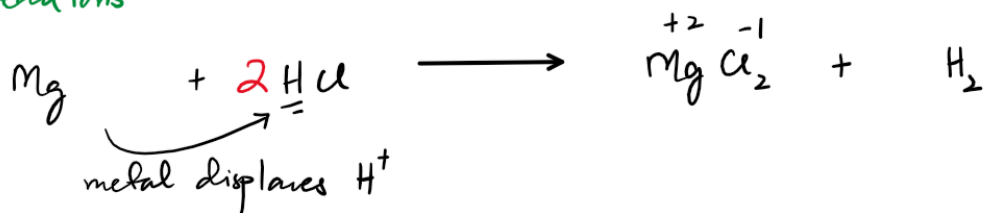
- * fewer ions produced, will conduct electricity but weakly
- * slower reactions compared to strong acids

Acid Reactions / Equations

1-



(MAZIT)

metals have
moderate
reactions

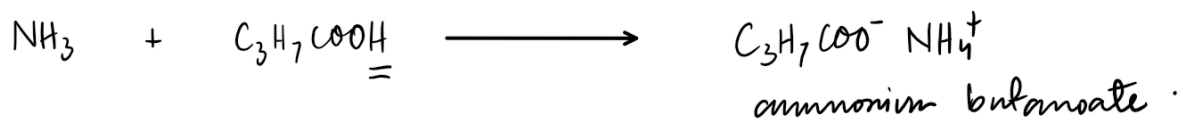
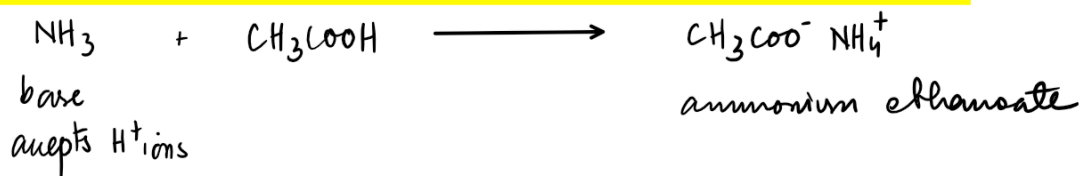
2. metal oxide / hydronide + acid $\longrightarrow$ salt + H_2O



3. metal carbonate + acid $\longrightarrow$ salt + H_2O + CO_2



4. Ammonia + Acid $\longrightarrow$ Ammonium Salt



Condensation Polyesters

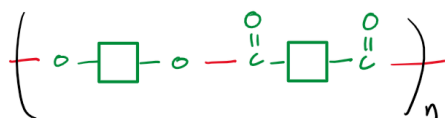
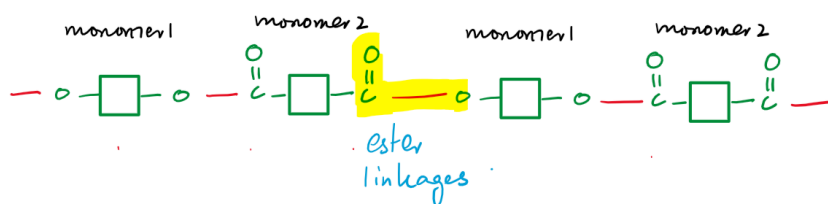
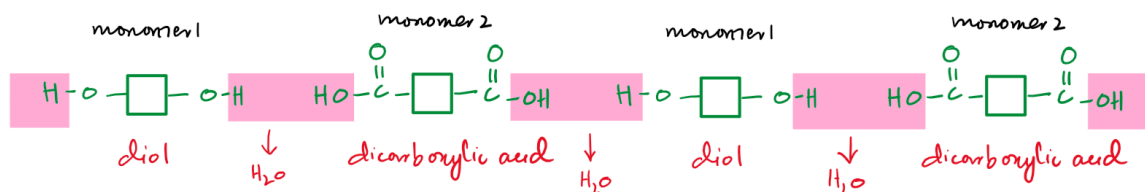
Condensation Polymers

→ water produced as a byproduct

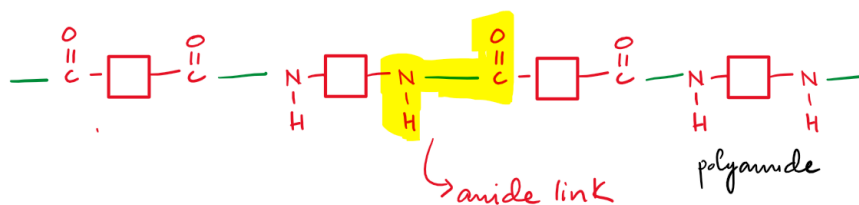
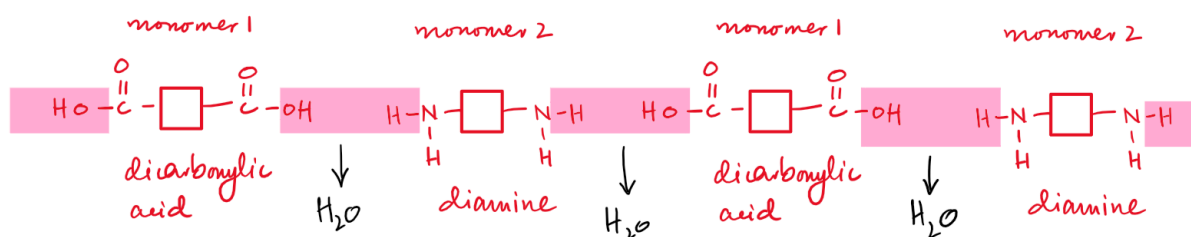
* condensation polymers are biodegradable (hydrolyse in water) (linkages are reactive)

* hydrolysis: heat with dilute acid/alkali

1. **Polyesters** terylene (clothes) - synthetic
fat molecules - natural

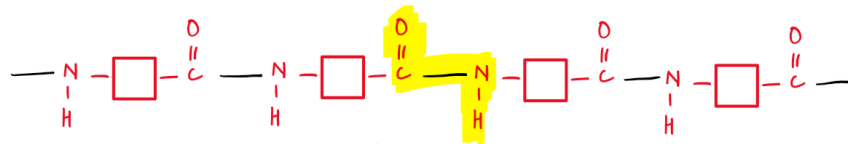
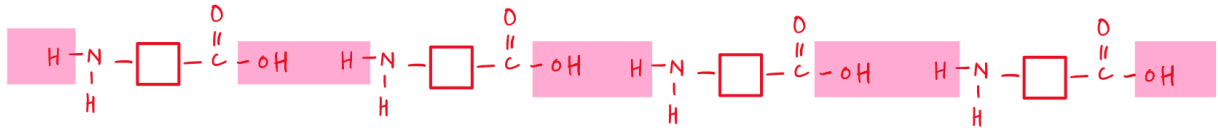


2. **Polyamide** (synthetic) e.g. nylon - fishing nets, ropes
Kevlar - bullet proof jackets



Proteins (Type of natural polyamide)

amino acid
monomers



polypeptide / polyamide (Proteins)

Starch (complex carbohydrate)

monomer

