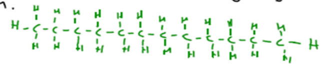
Topic 10 - Organic Chemistry

10.1 Introduction

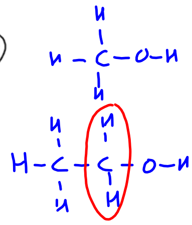
Part 1 What is a homologous series?

C, H, O, N, P, S

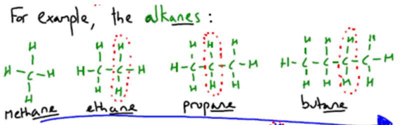
Organic compounds are compounds that are based around a chain of carbon atoms. Carbons form relatively strong bonds with other carbons and hydrogens so we can end up with very long chains of them.



This fact gives rise to the possibility of a homologous series. This is a series of compounds with the same general formula and the same functional group (for example an alcohol group (-OH)) but they differ only by the presence of an extra -CH₂- group in the carbon chain.

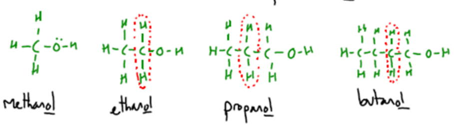


For example, the alkanes:

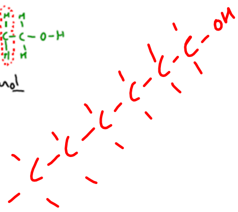


These compounds gain one -CH₂- group each time.
This is called a methylene group.

Example 2, a homologous series of alcohols:

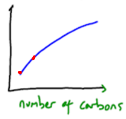


adding a -CH₂- group



Compounds in a homologous series will have similar chemical properties as they contain the same functional groups (such as an alcohol group).

Compounds in a homologous series will have physical properties (eg. boiling point) that vary in a regular and predictable manner. For example, the boiling points of alkanes:



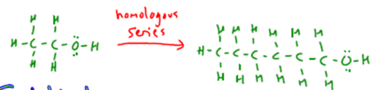
Why does the gradient of this curve decrease?
Each time I add a methylene (CH_2) group the percentage increase in size becomes smaller, so the percentage increase in Van der Waals forces also becomes smaller.

But Mr Canning, what about solubility in water???

Most organic compounds are non-polar (have no permanent dipole) and have long carbon chains. Therefore they cannot dissolve in water.

"Remember - to dissolve in water a molecule must be able to replace the strong intermolecular forces between the water molecules with forces of a similar strength."

If a molecule is very polar or can form H-bonds then it will be able to dissolve in water. However, as the carbon chain increases → the solubility decreases.



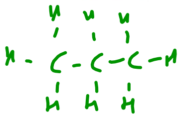
This is because more and more of the molecule becomes unable to form strong intermolecular forces with the water.

How are these photos related to homologous series?

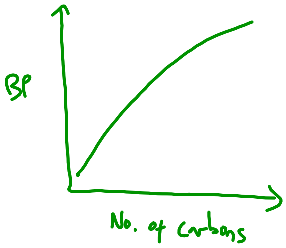
Crude oil





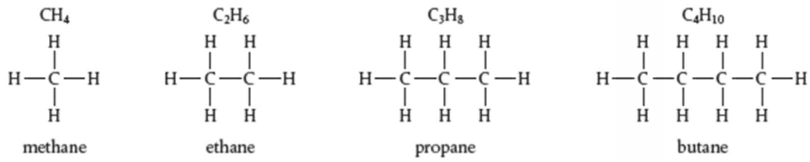



Fractional distillation

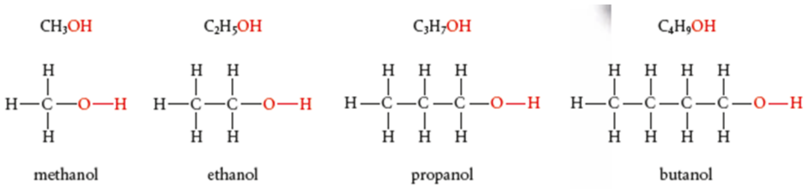


C-C-C-C-C

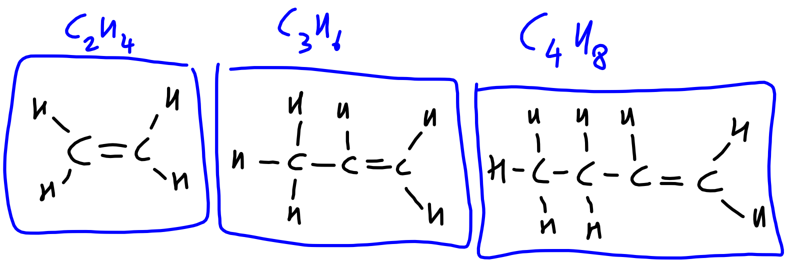
What are the general formulas for these homologous series?



C_nH_{2n+2}



$C_nH_{2n+1}OH$



C_nH_{2n}

American Lobbying Council

2013 - American Renewable Energy and Efficiency Act

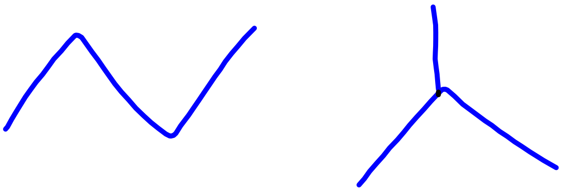
1. BP gas
2. Greenpeace
3. Government of Venezuela
4. Tesla Motors

Argue the case from the point of view of your agenda.

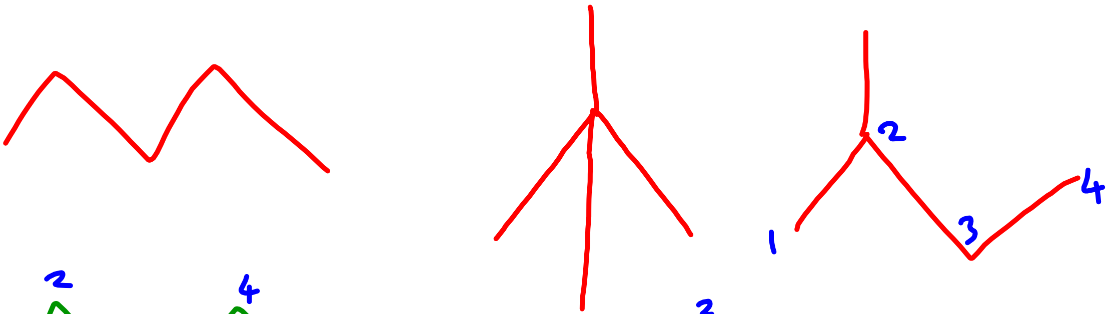
- 20 min preparation
- < 5 min presentation from your group on the issue.
- 10 min to prepare possible counter arguements.
- 20 min debate.

How many structural isomers can each of the following molecular formulas have?

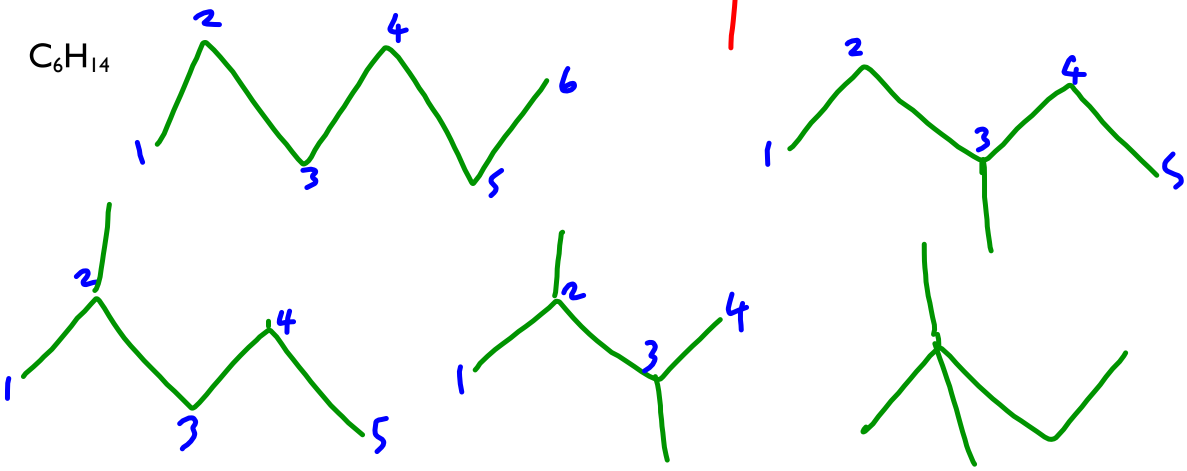
C_4H_{10}



C_5H_{12}



C_6H_{14}



You have drawnfull structural formulas that show every bond. Now write condensed structural formulas for each one.

These are structural isomers as they have the same molecular formula (C6H14) but different a different arrangement of atoms .

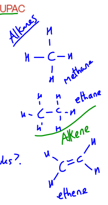
As we can see here the number of isomers that exist for a molecular formula increases as the molecular size increases. In fact the increase is exponential; there are 75 possible isomers of $C_{10}H_{22}$ and 366 319 of $C_{20}H_{42}$!

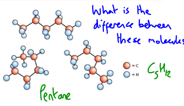
Nomenclature for organic compounds: the IUPAC system

Rule 1: Identify the longest straight chain of carbon atoms

The longest chain of carbon atoms gives the **stem** of the name as follows.

Number of carbon atoms in longest chain	Stem in IUPAC name	Example of compound
1	meth-	CH_4, methane
2	eth-	C_2H_6, ethane
3	prop-	C_3H_8, propane
4	but-	C_4H_{10}, butane
5	pent-	C_5H_{12}, pentane
6	hex-	C_6H_{14}, hexane

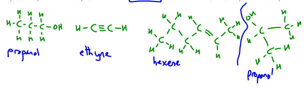




What is the difference between these molecules?

Rule 2: Identify the functional group

Class	Functional group	Name of functional group	Suffix in IUPAC name	Example of compound	General formula
alkane			-ane	C_2H_6, ethane	C_nH_{2n+2}
alkene	$>C{=}C<$	alkenyl	-ene	$H_2C{=}CH_2$, ethene	C_nH_{2n}
alkyne	$-C{\equiv}C-$	alkynyl	-yne	$HC{\equiv}CH$, ethyne	C_nH_{2n-2}
alcohol	$-OH$	hydroxyl	-anol	C_2H_5OH, ethanol	$C_nH_{2n+1}OH$

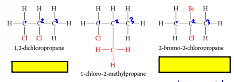


Rule 3: Identify the side chains or substituent groups

Class	Functional group	Name of functional group	Prefix in IUPAC name	Example of compound
alkane			methyl, ethyl, propyl, etc.	$CH_3CH(CH_3)C_2H_5$, 2-methylbutane $CH(C_2H_5)_3$, 3-ethylpentane $CH(C_3H_7)_3$, 4-propylheptane
halogenoalkane	$-F$, $-Cl$, $-Br$, $-I$	halogeno	fluoro, chloro, bromo, iodo	C_2H_5Cl, chloroethane $CH_3CH_2BrCH_3$, 2-bromopropane
amine	$-NH_2$	amine	amino	$CH_2(NH_2)COOH$, 2-aminoethanoic acid

If there is more than one substituent group of the same type, we use commas between the numbers and the prefixes di-, tri-, or tetra- before the name. Substituents are given in order of the number of the carbon atom to which they are attached; if there is more than one group on the same atom they are put in alphabetical order.

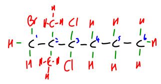
For example:



1,2-dichloropropane   1-chloro-2-methylpropane   2-bromo-2-chloropropane

1,2-dichloropropane   1-chloromethylpropane   2-bromo-2-chloropropane

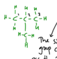
1-bromo-3,3-dichloro-2,2-dimethylhexane



Group of compounds #1 - Alkanes

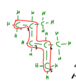
Alkanes are compounds made of ONLY carbons, hydrogen and single bonds.

Methane — 1 carbon — it is an alkane



2-methylpropane — 1 C — Put on the end so it sounds better! — main chain has 3 carbons — alkane

The side group comes off the 2nd carbon in the main chain



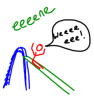
2,4-dimethylpentane

The methyl group comes of the 2nd and 4th carbon of the main chain.

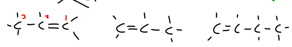
Important: It tells us clearly that there are 2 seperate methyl groups.

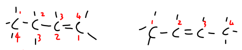
Group of compound #2 - alkenes → C=C

Alkenes are very similar to alkanes but they can have double bonds between carbons.

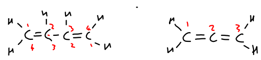


Draw ~~methene~~?





but-1-ene   but-2-ene



but-1,3-diene   prop[1,2]diene

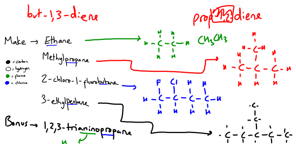
Make → Ethane → CH_3CH_3

Methylpropane

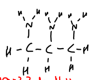
2-chloro-1-fluorobutane

3-ethylpentane

Bonus → 1,2,3-triaminopropane



amino = $-NH_2$

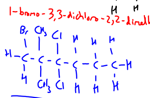


$CH_3CH_2CH(C_2H_5)CH_2CH_3$

$CH_2FCHClCH_2CH_3$

$CH_2F-CHCl-CH_2-CH_3$

1-bromo-3,3-dichloro-2,2-dimethylhexane



$CH_2BrC(CH_3)_2CCl_2CH_2CH_2CH_3$

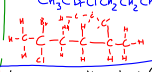
1.

~~3-iodobut-4-ene~~

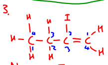
2-iodobut-1-ene

2

$CH_3CBrClCH_2CH_2CH(C_3H_7)CH_3$



3.



Name + SF

4. Draw all possible structures of C_2H_6O

* make

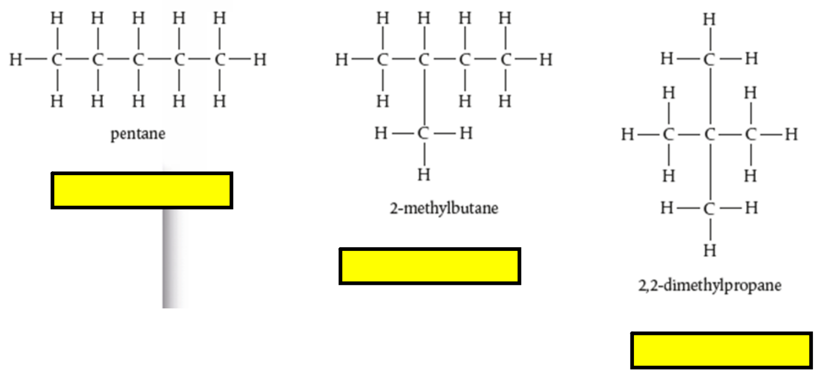
5. Draw + write SFs for → 1,1-diaminoprop-1-ene

→ 2-bromo-1-chloro-3-iodo-2-ethylpentane

Structural isomers in alkanes

We say alkanes are "saturated " compounds

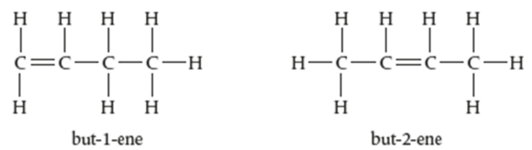
• C_5H_{12} has the following isomers:



Structural isomers in alkenes

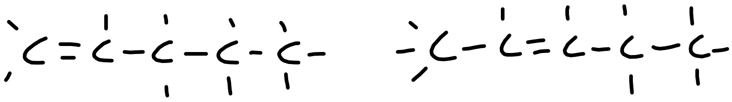
A different type of structural isomer occurs when the carbon–carbon double bond is found in different positions.

• C_4H_8 has the following straight-chain isomers:

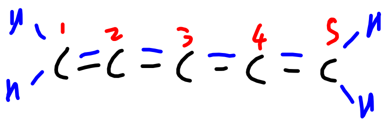


We say alkenes are "unsaturated " compounds

How many structural isomers do pentene and hexene have?



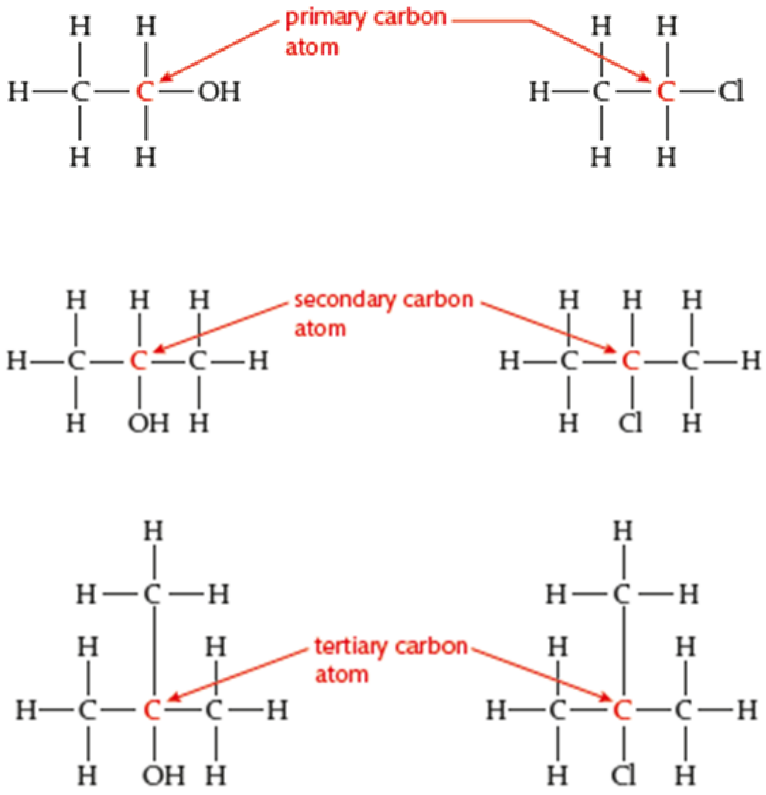
$CH_2CHCH_2CH_2CH_3$ $CH_3CHCHCH_2CH_3$

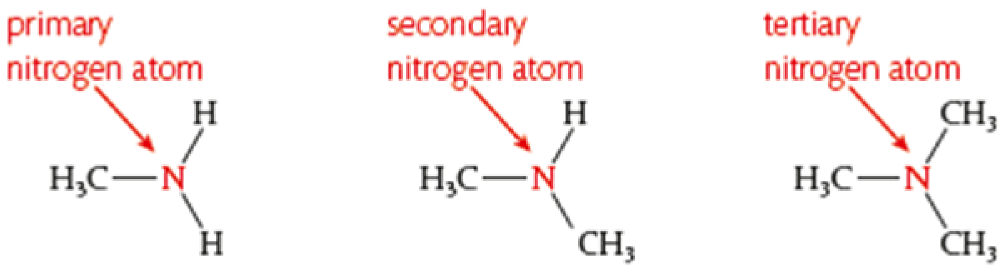


pent-1,2,3,4-tetraene

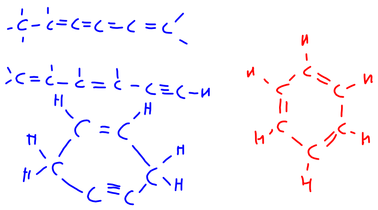
Selectividad - We must also consider position isomerism and functional group isomerism.

Primary, secondary, and tertiary compounds





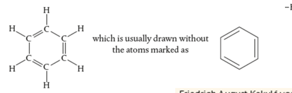
How many structural isomers can be drawn of C_6H_6?



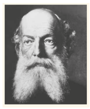
Benzene does not behave like other unsaturated molecules

The 1 : 1 ratio of carbon to hydrogen in benzene, C_6H_6, indicates a high degree of unsaturation, greater than that of alkenes or alkynes. Yet early observations on benzene indicated that it does not show the characteristic properties of possible structures such as:

In 1865 Kekulé suggested a cyclic arrangement of the carbon atoms with alternating single and double bonds. This is 1,3,5-cyclohexatriene:

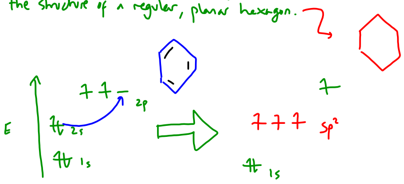


–H

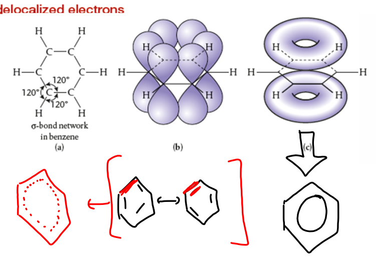


Friedrich August Kekulé von Stradonitz (1829–1896)

However, X-ray crystallography showed that it had the structure of a regular, planar hexagon.

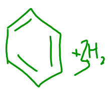


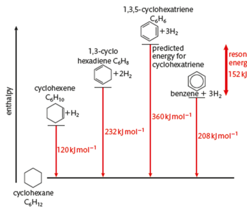
The special stability of the benzene ring is the result of delocalized electrons



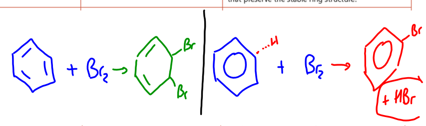
What evidence is there for this structure of benzene?

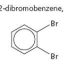
Property	Observation / evidence	Explanation
1 Bond lengths	All carbon–carbon bond lengths in benzene are equal and intermediate in length between single and double bonds.	Each bond contains a share of three electrons between the bonded atoms. X-ray bond length data / nm: alkane single bond C—C 0.154 nm alkene double bond C═C 0.134 nm benzene  0.139 nm
2 $\Delta H_{hydrogenation}$ for the reaction $C_6H_6 + 3H_2 \rightarrow C_6H_{12}$		





3 Type of reactivity	Benzene is reluctant to undergo addition reactions and is more likely to undergo substitution reactions.	Addition reactions are energetically not favoured as they would involve disrupting the entire cloud of delocalized electrons. The resonance energy would have to be supplied and the product, without the delocalized ring of electrons, would be *less* stable. Benzene can instead undergo substitution reactions that preserve the stable ring structure.



4 Isomers	Only one isomer exists of compounds such as 1,2-dibromobenzene.	As benzene is a symmetrical molecule with no alternating single and double bonds, all adjacent positions in the ring are equal. For example 1,2-dibromobenzene, $C_6H_4Br_2$ 

Exercises

5 Draw and name all the structural isomers of $C_3H_3Cl_5$.

6 Which formula is that of a secondary halogenoalkane?

A $CH_3CH_2CH_2CH_2Br$ **B** $CH_3CHBrCH_2CH_3$ **C** $(CH_3)_2CHCH_2Br$ **D** $(CH_3)_3CBr$

7 Describe the bonding in a benzene molecule and use it to explain benzene's energetic stability.

8 **(a)** When comparing the boiling points of different classes of compound, why is it important to choose molecules that have similar molar mass?

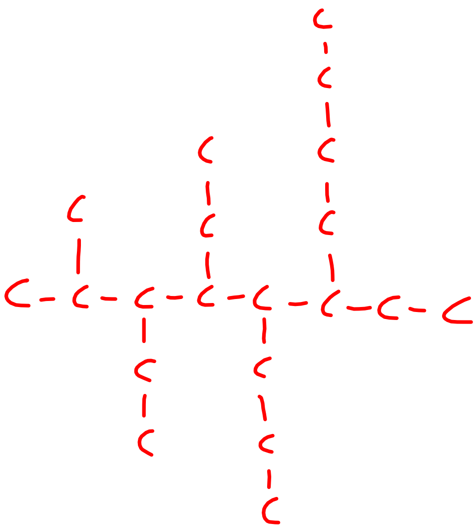
(b) Explain how you would expect the solubility of alcohols in hexane to change with increasing chain length.

Lab reports → Design for Marking

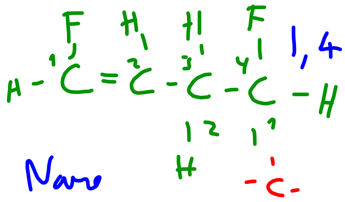
3rd evaluation → Topic 1, 5/15, 4/14

Final exam → Topic 1, 10, 2/12, 3/13

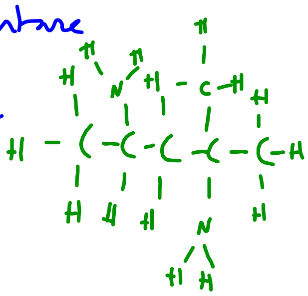
1
2, 12 Atomic structure
3, 13 periodicity
4, 14 Bonding
5, 15 Energetics
10



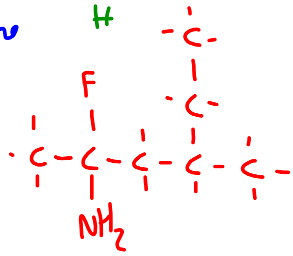
Draw: 2,4-diamino-4-methylpentane

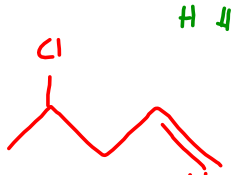


1,4-difluorobut-1-ene

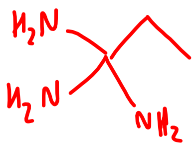


Name





4-chloropent-1-ene



10.2 Functional group chemistry

Understandings:

- **Alkanes:** have low reactivity and undergo free radical substitution reactions.
- **Alkenes:** are more reactive than alkanes and undergo addition reactions. Bromine water can be used to distinguish between alkenes and alkanes.
- **Alcohols:** undergo nucleophilic substitution reactions with acids (also called esterification or condensation) and some undergo oxidation reactions.
- **Halogenoalkanes:** are more reactive than alkanes. They can undergo (nucleophilic) substitution reactions. A nucleophile is an electron-rich species containing a lone pair that it donates to an electron-deficient carbon.
- **Polymers:** addition polymers consist of a wide range of monomers and form the basis of the plastics industry.
- **Benzene:** does not readily undergo addition reactions but does undergo electrophilic substitution reactions.

Applications and skills:

- **Alkanes:**
  - Writing equations for the complete and incomplete combustion of hydrocarbons.
  - Explanation of the reaction of methane and ethane with halogens in terms of a free radical substitution mechanism involving photochemical homolytic fission.
- **Alkenes:**
  - Writing equations for the reactions of alkenes with hydrogen and halogens and of symmetrical alkenes with hydrogen halides and water.
  - Outline of the addition polymerization of alkenes.
  - Relationship between the structure of the monomer to the polymer and repeating unit.
- **Alcohols:**
  - Writing equations for the complete combustion of alcohols.
  - Writing equations for the oxidation reactions of primary and secondary alcohols (using acidified potassium dichromate(VI) or potassium manganate(VII) as oxidizing agents). Explanation of distillation and reflux in the isolation of the aldehyde and carboxylic acid products.
  - Writing the equation for the condensation reaction of an alcohol with a carboxylic acid, in the presence of a catalyst (e.g. concentrated sulfuric acid) to form an ester.
- **Halogenoalkanes:**
  - Writing the equation for the substitution reactions of halogenoalkanes with aqueous sodium hydroxide.

Guidance

- *Reference should be made to initiation, propagation, and termination steps in free radical substitution reactions. Free radicals should be represented by a single dot.*
- *The mechanisms of S_N1 and S_N2 and electrophilic substitution reactions are not required.*

Alkanes

Why are they so unreactive?
- Strong bonds
- Non-polar

Br	193	285	219	249	366	178		2
C	285	346	324	492	414	228	286	3
Cl	219	324	242	255	431	211	192	2
F	249	492	255	159	567	280	278	1
H	366	414	431	567	436	298	391	4
I	178	228	211	280	298	151		2
N		286	192	278	391		158	2
O	201	358	206	191	463	201	214	1
P	264	264	322	490	322	184		3
S	218	289	271	327	364			
Si	330	307	400	597	323	234		4

So why are they so useful for fuels?
- Bonds in products → O=C=O   H–O–H

Multiple bonds (kJ mol^{-1})

C=C	614	C≡N	890
C≡C	839	C=O	804
C⩵C (in benzene)	507	C=S	536
C=N	615	N=N	470

Complete and incomplete combustion?

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

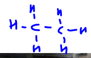
However, when the oxygen supply is limited, incomplete combustion occurs giving rise to carbon monoxide and water. For example:

$$2C_3H_8(g) + 7O_2(g) \rightarrow 3CO(g) + H_2O(g)$$

In conditions of extreme oxygen limitation, carbon will also be produced. For example:

$$C_3H_8(g) + 2O_2(g) \rightarrow 3C(g) + 4H_2O(g)$$

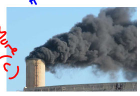
Soot



H−C≡C−H

Burning alkanes

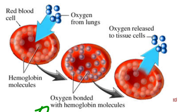
More soot (C) as higher C:H ratio



Burning alkynes

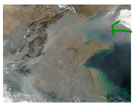
Problems? $C + O_2 \rightarrow CO_2$

Global warming



CO is poisonous

Soot
Global Dimming



Smog

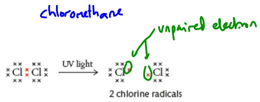
Substitution reactions of alkanes: halogenation

$$CH_4(g) + Cl_2(g) \xrightarrow{\text{UV light}} CH_3Cl(g) + HCl(g)$$

chloromethane

Initiation

$$Cl_2 \xrightarrow{\text{UV light}} 2\ Cl\bullet \text{ radicals}$$

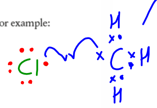


"Photochemical homolytic fission"

Propagation

Propagation reactions both use and produce free radicals. For example:

$$Cl\bullet + CH_4 \rightarrow CH_3\bullet + HCl$$
$$CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$$
$$CH_3Cl + Cl\bullet \rightarrow CH_2Cl\bullet + HCl$$
$$CH_2Cl\bullet + Cl_2 \rightarrow CH_2Cl_2 + Cl\bullet$$

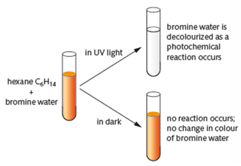


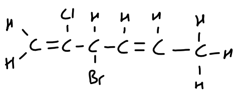
There are many possible propagation steps, which all allow the reaction to continue. This is why this type of reaction is often called a **chain reaction**.

Termination

Termination reactions remove free radicals from the mixture by causing them to react together and pair up their electrons. For example:

$$Cl\bullet + Cl\bullet \rightarrow Cl_2$$
$$CH_3\bullet + Cl\bullet \rightarrow CH_3Cl$$
$$CH_3\bullet + CH_3\bullet \rightarrow C_2H_6$$



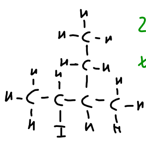


3-Bromo-2-Clorohex-1,4-diene

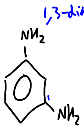
but-1,3-diyne

H−C≡C−C≡C−H

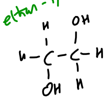
2-iodo-3-methylpentane

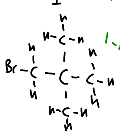


1,3-diaminobenzene



ethan-1,2-diol

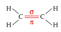




1-bromo-2,2-dimethylpropane

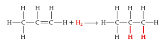
Alkenes

- General formula C_nH_{2n}.
- Alkenes are **unsaturated hydrocarbons** containing a carbon–carbon double bond.



Addition of hydrogen

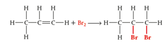
Hydrogen reacts with alkenes to form alkanes in the presence of a nickel catalyst at about 150 °C.



$CH_3CHCH_2 + H_2 \xrightarrow[150\,°C]{Ni\ catalyst} CH_3CH_2CH_3$
propene → propane

Addition of halogens

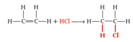
Halogens react with alkenes to produce dihalogeno compounds. These reactions happen quickly at room temperature, and are accompanied by the loss of colour of the reacting halogen. Note that the name and structure of the product indicates that a halogen atom attaches to each of the two carbon atoms of the double bond.



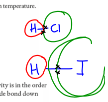
$CH_3CHCH_2 + Br_2 \longrightarrow CH_3CHBrCH_2Br$
propene → 1,2-dibromopropane

Addition of halogen halides

Hydrogen halides, such as HCl and HBr, react with alkenes to produce halogenoalkanes. These reactions take place rapidly in solution at room temperature.

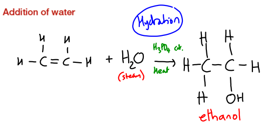


$CH_2CH_2 + HCl \longrightarrow CH_3CH_2Cl$
ethene → chloroethane

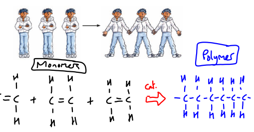


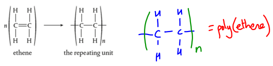
All the hydrogen halides are able to react in this way, but the reactivity is in the order HI > HBr > HCl due to the decreasing strength of the hydrogen halide bond down Group 17. So HI, with the weakest bond, reacts the most readily.

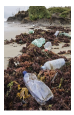
Addition of water

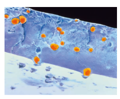


Polymerization of alkenes



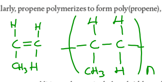




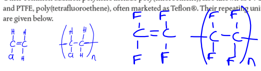


Coloured scanning electron micrograph of a section through a sheet of a biodegradable plastic. The orange spheres are granules of starch embedded in the plastic. When the plastic is buried in soil, the starch grains take up water and expand. This breaks the plastic into many small fragments, increasing the contact area with bacteria in the soil which digest the plastic. Such plastics help to address the major problem of waste plastic disposal.

Similarly, propene polymerizes to form poly(propene), often called polypropylene.



Other common addition polymers include poly(chloroethene), also known as PVC, and PTFE, poly(tetrafluoroethene), often marketed as Teflon®. Their repeating units are given below.



Exercises

9 Write equations for the following reactions:
(a) incomplete combustion of pentane, forming CO(g)
(b) complete combustion of butane
(c) incomplete combustion of propyne, forming C(s).

10 Write equations showing possible steps leading to a mixture of products in the reaction between bromine and ethane reacting together in UV light.

11 Give the name and structure of the products of the following reactions:
(a) $CH_3CH_2CH{=}CH_2 + H_2$ over Ni catalyst
(b) $CH_3CH{=}CHCH_3$ + conc. H_2SO_4
(c) $CH_3CH{=}CHCH_3 + HBr$

12 What would you observe during the following experiments carried out in test tubes at room temperature?
(a) some bromine water is added to cyclohexane in a test tube covered in aluminium foil

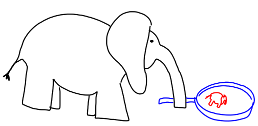
9 (a) $C_5H_{14}(l) + 6O_2(g) \rightarrow 5CO(g) + 7H_2O(l)$
(b) $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$
(c) $C_3H_4(g) + O_2(g) \rightarrow 3C(s) + 2H_2O(l)$

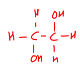
10 Bromine + ethane
initiation
$Br_2 \xrightarrow{UV\ light} 2Br^\bullet$ bromine radicals
propagation
$Br^\bullet + C_2H_6 \rightarrow C_2H_5^\bullet + HBr$
$C_2H_5^\bullet + Br_2 \rightarrow C_2H_5Br + Br^\bullet$
$C_2H_5Br + Br^\bullet \rightarrow C_2H_4Br^\bullet + HBr$
$C_2H_4Br^\bullet + Br_2 \rightarrow C_2H_4Br_2 + Br^\bullet$
termination
$Br^\bullet + Br^\bullet \rightarrow Br_2$
$C_2H_5^\bullet + Br^\bullet \rightarrow C_2H_5Br$
$C_2H_5^\bullet + C_2H_5^\bullet \rightarrow C_4H_{10}$
Overall, these reactions show how a mixture of products is formed.

11 (a) $CH_3CH_2CH_2CH_3$ butane
(b) $CH_3CH_2CH(OH)CH_3$ butan-2-ol
(c) $CH_3CH_2CHBrCH_3$ 2-bromobutane

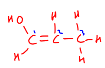
12 (a) No observable change.
(b) Burns with very smoky flame.
(c) The bromine water changes from brown to colourless.

My elephant preparing beautiful pancakes

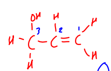




eth-1,2-diol



1-hydroxyprop-1-ene



3-hydroxyprop-1-ene

Alcohols

- General formula $C_nH_{2n+1}OH$
- Alcohols have —OH functional group

hydroxy

Combustion: alcohols as fuels

Write a balanced equation for the combustion of methanol and pentanol:

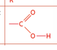
$2CH_3OH + ?O_2 \rightarrow 2CO_2 + 4H_2O$ $\Delta H_c^\ominus = -726.1\ kJ\ mol^{-1}$

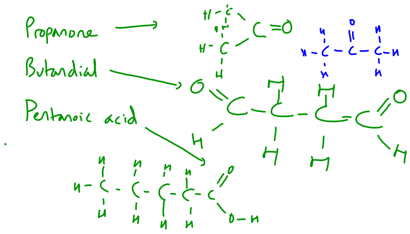
$2C_5H_{11}OH + 15O_2 \rightarrow 10CO_2 + 12H_2O$ $\Delta H_c^\ominus = -3330.9\ kJ\ mol^{-1}$

Oxidation of alcohols

Combustion involves the *complete* oxidation of the alcohol molecules, but it is also possible for them to react with oxidizing agents which selectively oxidize the carbon atom attached to the —OH group, keeping the carbon skeleton of the molecule

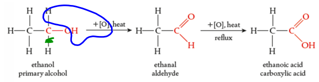
Before we look at these oxidations we must learn 3 more functional groups: ketones, aldehydes and carboxylic acids :

aldehyde		aldehyde (carbonyl)	-anal	C_2H_5CHO, propanal	R—CHO
ketone		carbonyl	-anone	CH_3COCH_3, propanone	R—CO—R′
carboxylic acid		carboxyl	-anoic acid	C_2H_5COOH, propanoic acid	$C_nH_{2n+1}COOH$



"Aldehyde the crab"

Primary alcohols are oxidized in a two-step reaction, first forming the **aldehyde**, which under prolonged conditions is oxidized further to the **carboxylic acid.** For example:



[O] = acified oxidising agent e.g. $K_2Cr_2O_7$ + acid
Potassium dichromate

ethanol (primary alcohol) $\xrightarrow{+[O],\ heat}$ ethanal (aldehyde) $\xrightarrow[reflux]{+[O],\ heat}$ ethanoic acid (carboxylic acid)

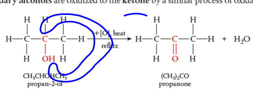
$H^+/Cr(VI) \longrightarrow Cr(III)$

How do we differentiate between collecting the aldehyde or the carboxylic acid?

Distillation → Allows me to collect aldehyde

Reflux → Carboxylic acid

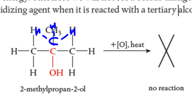
Secondary alcohols are oxidized to the **ketone** by a similar process of oxidation



propan-2-ol ($CH_3CHOHCH_3$) $\xrightarrow[reflux]{+[O],\ heat}$ propanone ($(CH_3)_2CO$) + H_2O

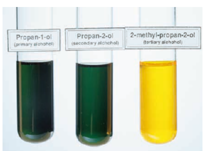
$H^+/Cr(VI) \longrightarrow Cr(III)$

Tertiary alcohols are not readily oxidized under comparable conditions. This would involve breaking the carbon skeleton of the molecule, which requires significantly more energy. Therefore we will not see a colour change in the potassium dichromate(VI) oxidizing agent when it is reacted with a tertiary alcohol.



2-methylpropan-2-ol $\xrightarrow{+[O],\ heat}$ no reaction

$H^+/Cr(VI) \longrightarrow$ no change in colour



Summary of oxidation of alcohols

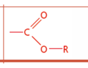
	Oxidation product	Colour change with acidified $K_2Cr_2O_7(aq)$
primary alcohol	aldehyde → carboxylic acid	orange → green
secondary alcohol	ketone	orange → green
tertiary alcohol	not oxidized	no colour change

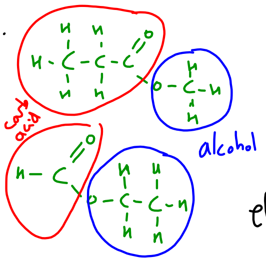
Esterification reaction

Alcohols react with carboxylic acids to form esters in a **condensation** reaction in which water is also produced.

carboxylic acid + alcohol ⇌ ester + water

What are esters?

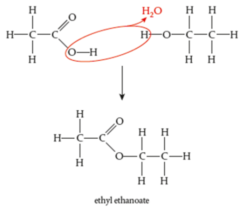
ester*		ester	-anoate	$C_2H_5COOCH_3$, methyl propanoate	R—COO—R'



methyl propanoate

ethyl ~~methanoate~~ methanoate

For example, the reaction between ethanoic acid and ethanol is as follows.



$$CH_3COOH + C_2H_5OH \xrightarrow{\text{conc. } H_2SO_4} CH_3COOC_2H_5 + H\text{-}O\text{-}H$$

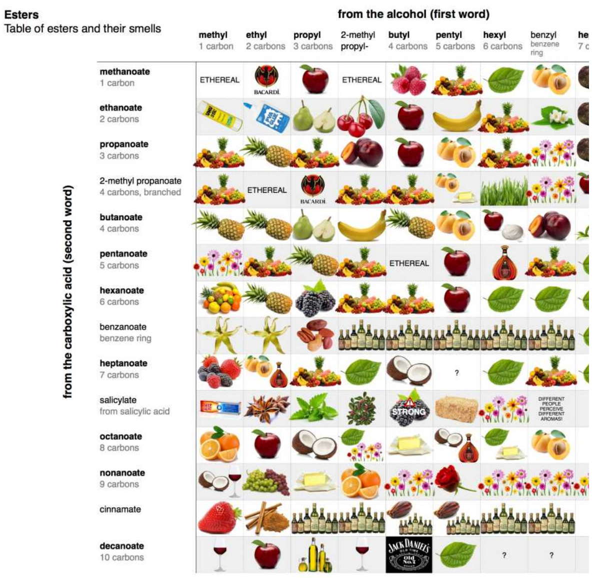
Some other esterification reactions are given below.

$$HCOOH + C_2H_5OH \rightleftharpoons HCOOC_2H_5 + H_2O$$

methanoic acid, ethanol, ethyl methanoate

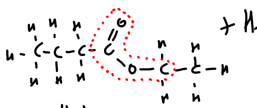
$$C_3H_7COOH + CH_3OH \rightleftharpoons C_3H_7COOCH_3 + H_2O$$

butanoic acid, methanol, methyl butanoate



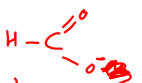
Name, draw + condensed structural formula of esters:

1. $CH_3CH_2CH_2COOCH_2CH_3$ →



+ H_2O

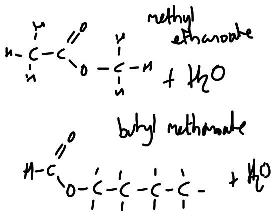
2. $CH_3\text{-}CH_2\text{-}CH_2\text{-}COO\text{-}CH_2\text{-}CH_3$ — ethyl butanoate



COOH

3. HCOOH → H^+ →

methyl ethanoate



+ H_2O

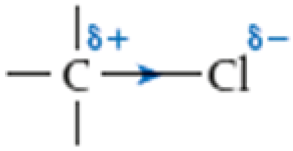
butyl methanoate

$HCOOCH_2CH_2CH_2CH_3$ + H_2O

HCOO-CH_3

Halogenoalkanes

- General formula is $C_nH_{2n+1}X$ (where X = halogen)
- Halogenoalkanes contain an atom of fluorine, chlorine, bromine, or iodine bonded to the carbon skeleton of the molecule.



Nucleophilic substitution

- Nucleophile -

The hydroxide ion, OH^-, is a good nucleophile. For example, halogenoalkanes react with alkalis such as NaOH to form alcohols.

$$CH_3Cl + NaOH \rightarrow CH_3OH + NaCl$$
chloromethane → methanol

$$C_3H_7Br + NaOH \rightarrow C_3H_7OH + NaBr$$
1-bromopropane → propan-1-ol

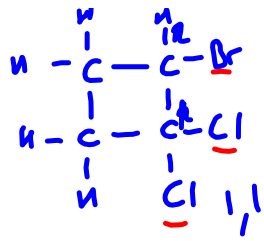
Designing an investigation:

Investigate an aspect of a homologous series.

Research → How does the BP change in a homologous series?

How does the number of carbon atoms in a homologous series of primary alcohols affect its boiling point?

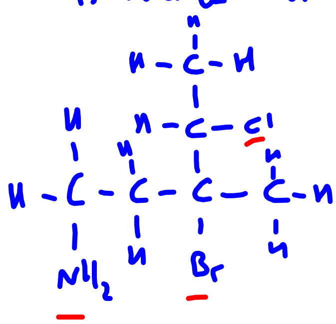
4. Name: a.



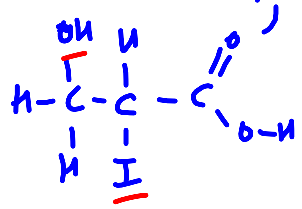
1,1,2

1,2,2

b.



c.



5. Condensed structural formulae of products

$C_3H_6 + Br_2 \longrightarrow CH_3CHBrCH_2Br$

$CH_3OH + HCOOH \longrightarrow HCOOCH_3$

$C_4H_8 + H_2 \longrightarrow CH_3CH_2CH_2CH_3$