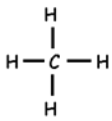
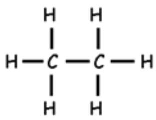
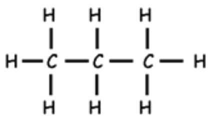
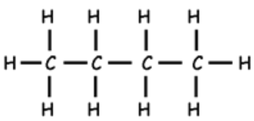
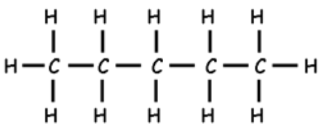
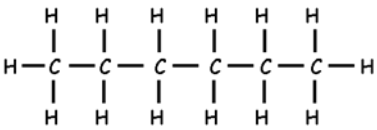
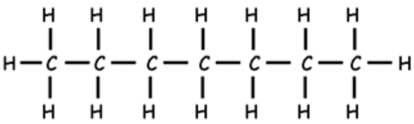
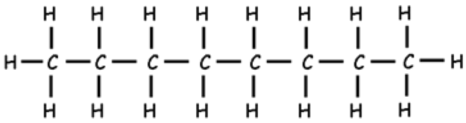
Unit 2—Nature's Chemistry Revision Notes

Homologous series: a group of compounds with the same general formula and similar chemical properties that show a gradual change in physical properties.
Examples include the **alkanes**, **alkenes**, **cycloalkanes**, **alkanols** and **alkanoic acids**.

Alkanes

General formula: C_nH_{2n+2}

Name	Structural formula	Shortened structural formula	Molecular formula
methane		CH_4	CH_4
ethane		CH_3CH_3	C_2H_6
propane		$CH_3CH_2CH_3$	C_3H_8
butane		$CH_3CH_2CH_2CH_3$	C_4H_{10}
pentane		$CH_3CH_2CH_2CH_2CH_3$	C_5H_{12}
hexane		$CH_3CH_2CH_2CH_2CH_2CH_3$	C_6H_{14}
heptane		$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$	C_7H_{16}
octane		$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	C_8H_{18}

Combustion: hydrocarbon + oxygen → carbon dioxide + water, e.g.

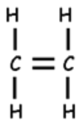
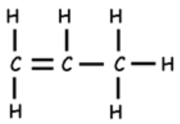
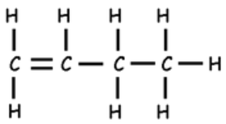
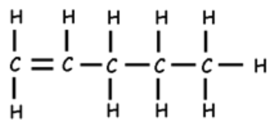
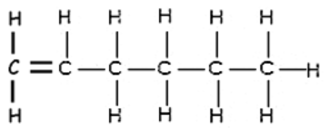
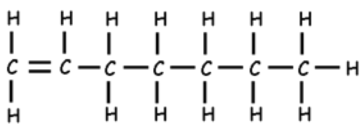
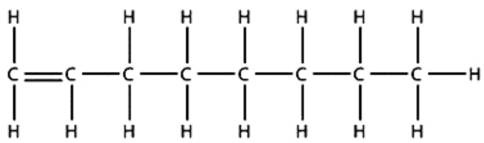
propane + oxygen → carbon dioxide + water

$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$

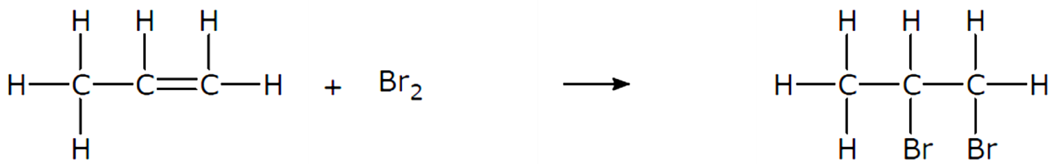
$C_3H_8 + \mathit{5}O_2 \rightarrow \mathit{3}CO_2 + \mathit{4}H_2O$

Alkenes

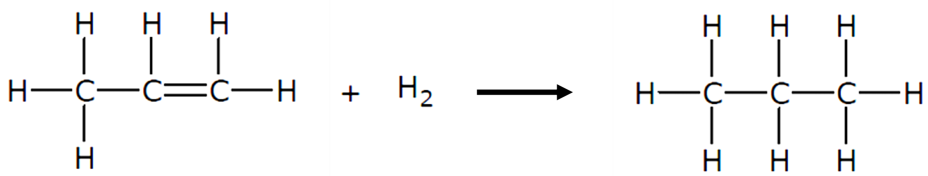
General formula: C_nH_{2n}

Name	Structural formula	Shortened structural formula	Molecular formula
ethene		$CH_2{=}CH_2$	C_2H_4
propene		$CH_3CH{=}CH_2$	C_3H_8
butene		$CH_3CH_2CH{=}CH_2$	C_4H_8
pentene		$CH_3CH_2CH_2CH{=}CH_2$	C_5H_{10}
hexene		$CH_3CH_2CH_2CH_2CH{=}CH_2$	C_6H_{12}
heptene		$CH_3CH_2CH_2CH_2CH_2CH{=}CH_2$	C_7H_{14}
octene		$CH_3CH_2CH_2CH_2CH_2CH_2CH{=}CH_2$	C_8H_{16}

Alkenes are **unsaturated** hydrocarbons and can undergo **addition** reactions.



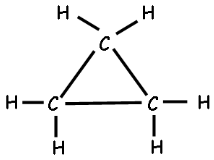
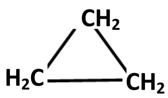
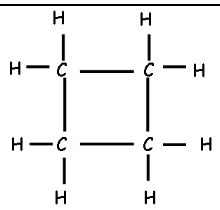
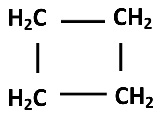
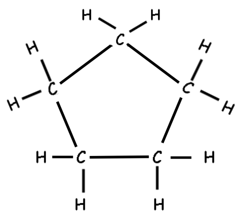
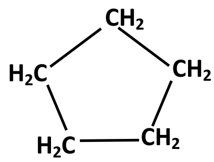
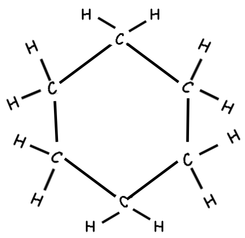
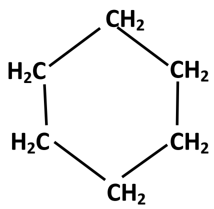
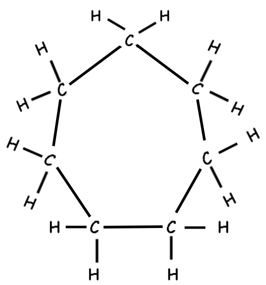
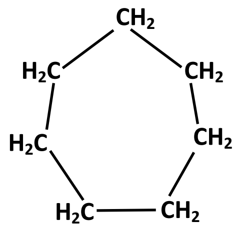
In this reaction bromine decolourises rapidly. This reaction is used as a test for unsaturation.



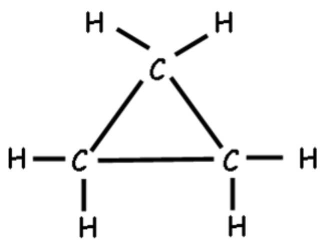
Hydrogenation - the addition of hydrogen, can convert alkenes into alkanes.

Cycloalkanes

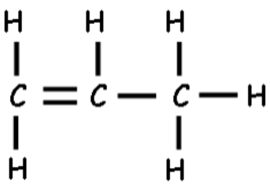
General formula: C_nH_{2n}

Name	Structural formula	Shortened structural formula	Molecular formula
cyclopropane			C_3H_8
cyclobutane			C_4H_8
cyclopentane			C_5H_{10}
cyclohexane			C_6H_{12}
cycloheptane			C_7H_{14}

The fact that the cycloalkanes and the alkenes have the same general formula, C_nH_{2n}, allows us to conclude that cycloalkanes are isomers of the corresponding alkene with the same number of carbon atoms.
For example;



is an isomer of



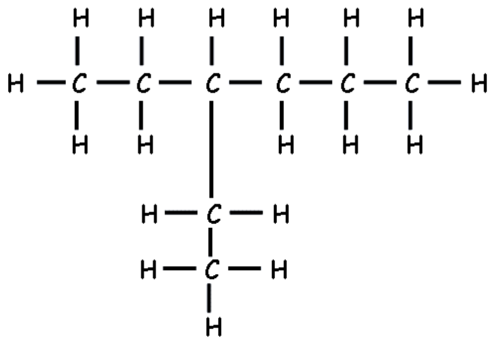
<u>Isomers</u>: same **molecular** formula **different structural** formulae**.**
Isomers have different properties, e.g. propene decolourises bromine solution, cyclopropane does not.

Systematic names

Structural formulae can be drawn and molecular formulae written from systematic names and vice versa.

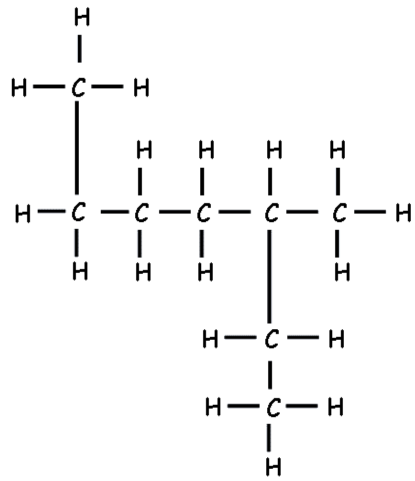
Rules

1. Identify and name the longest chain of carbon atoms.
2. Identify the branch and name it according to the number of carbon atoms in the branch.
3. Number the branch so that it has the lowest possible number.



3-ethylhexane

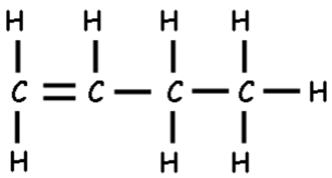
$CH_3CH_2CH(CH_2CH_3)CH_2CH_2CH_3$



3-methylheptane

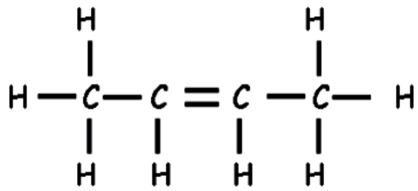
$CH_3CH_2CH(CH_3)CH_2CH_2CH_2CH_3$

4. Alkenes are named by numbering the carbon atoms from the end that gives the carbon of the double bond the lowest number.
5. Where there are branches, the double bond takes priority over the branch.



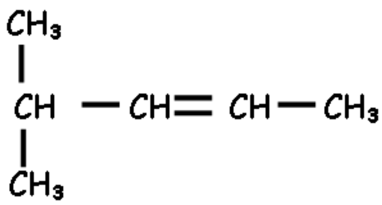
but-1-ene

$CH=CHCH_2CH_3$



but-2-ene

$CH_3CH=CHCH_3$



4-methylpent-2-ene

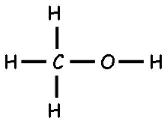
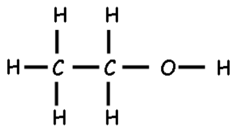
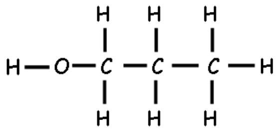
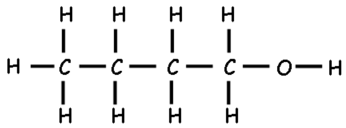
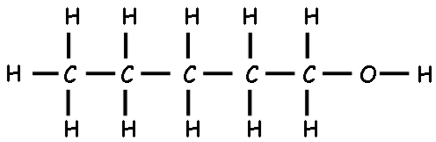
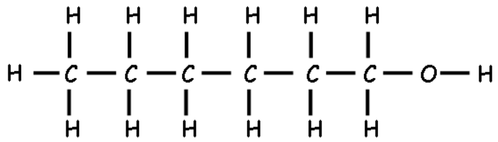
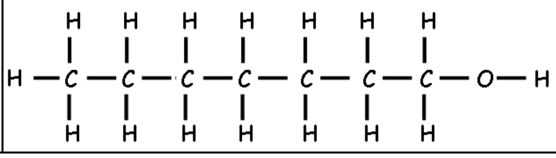
$CH_3CH(CH_3)CH=CHCH_3$

Alcohols

Functional group: **hydroxyl** group **(-OH)**

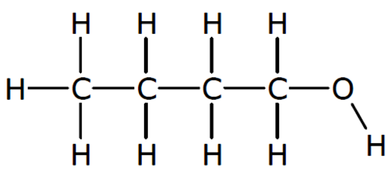
Alkanols: homologous series of alcohols

General formula: $C_nH_{2n+1}OH$

Name	Structural formula	Shortened structural formula	Molecular formula
methanol		CH_3OH	CH_3OH
ethanol		CH_3CH_2OH	C_2H_5OH
propanol		$CH_3CH_2CH_2OH$	C_3H_7OH
butanol		$CH_3CH_2CH_2CH_2OH$	C_4H_9OH
pentanol		$CH_3CH_2CH_2CH_2CH_2OH$	$C_5H_{11}OH$
hexanol		$CH_3CH_2CH_2CH_2CH_2CH_2OH$	$C_6H_{13}OH$
heptanol		$CH_3CH_2CH_2CH_2CH_2CH_2CH_2OH$	$C_7H_{15}OH$

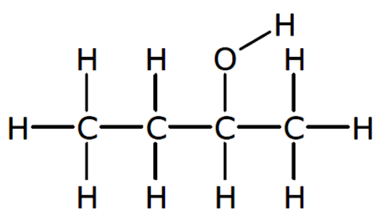
Isomers

e.g. butanol



butan-1-ol

$CH_3CH_2CH_2CH_2OH$



butan-2-ol

$CH_3CH_2CH(OH)CH_3$

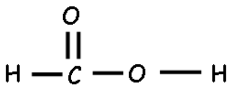
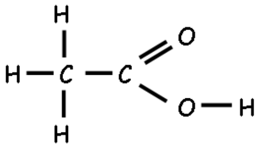
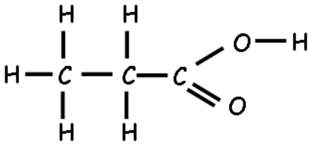
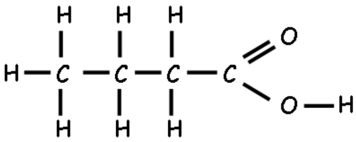
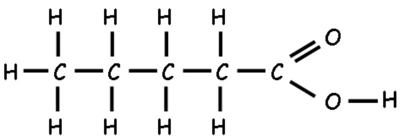
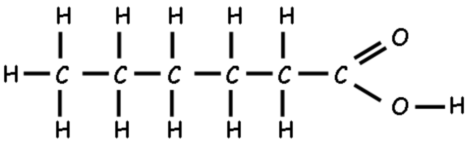
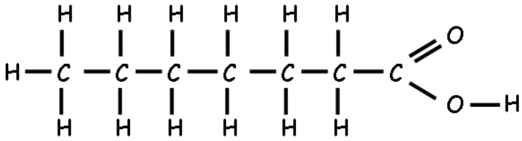
Alcohols are effective solvents, highly flammable, and burn with very clean flames resulting in their use as fuels.

Carboxylic acids

Functional group: **carboxyl** group **(-COOH)**

Alkanoic acids: homologous series of carboxylic acids

General formula: $C_nH_{2n+1}COOH$

Name	Structural formula	Shortened structural formula	Molecular formula
methanoic acid		HCOOH	HCOOH
ethanoic acid		CH_3COOH	CH_3COOH
propanoic acid		CH_3CH_2COOH	C_2H_5COOH
butanoic acid		$CH_3CH_2CH_2COOH$	C_3H_7COOH
pentanoic acid		$CH_3CH_2CH_2CH_2COOH$	C_4H_9COOH
hexanoic acid		$CH_3CH_2CH_2CH_2CH_2COOH$	$C_5H_{11}COOH$
heptanoic acid		$CH_3CH_2CH_2CH_2CH_2CH_2COOH$	$C_6H_{13}COOH$

Vinegar is a solution of ethanoic acid.
Vinegar is used in household cleaning products designed to remove limescale (a build up of insoluble carbonates on plumbing fixtures) and as a preservative in the food industry.

Esters

An ester can be made by reacting a carboxylic acid with an alcohol.
Esters are used in food flavouring, industrial solvents, fragrances and materials.

Energy from fuels

Alkanes and alcohols can be used as fuels.

Combustion reactions are **exothermic** reactions.

Exothermic reactions release heat energy to the surroundings.
Endothermic reactions take in heat energy from the surroundings.

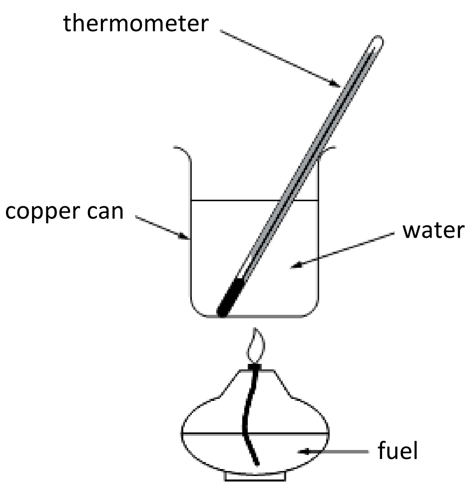
Calculations based on equations

When a substance is combusted the reaction can be represented using a balanced formulae equation.
The quantities of reactants and products in these reactions can be calculated.
E.g. Calculate the mass of oxygen required to burn 50g of butan-1-ol.

$C_4H_9OH(l)$	+	$6O_2(g)$	→	$4CO_2(g)$	+	$5H_2O(l)$
1mol	reacts with	6mol				
74g	⟷	192g				
50g	⟷	$\frac{50 \times 192}{74}$				
		= 130g				

Energy calculations

Different fuels provide different quantities of energy and this can be measured experimentally and calculated using $E_h = cm\Delta T$.



$$E_h = cm\Delta T$$

- Energy (kJ)
- Specific heat capacity of water ($kJ\,kg^{-1}\,^{o}C^{-1}$) = 4.18
- Mass of water heated (kg) $1cm^3 = 0.001kg$
- Change in temperature (^{o}C)

$$\text{Energy per gram } (kJ\,g^{-1}) = \frac{E_h}{\text{Mass of fuel burned (g)}}$$