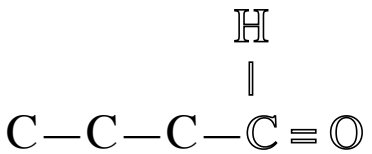
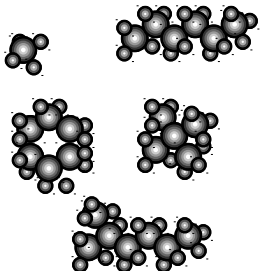
# Higher Chemistry





*Unit 2:*

# Nature's Chemistry

Student:

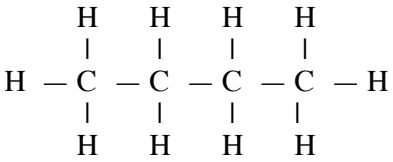
# *Pupil Notes Part 2*

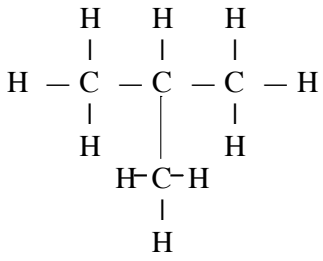
# *Structures & Naming*

# 5.2 Naming Molecules

*This lesson largely revises the principles behind naming and how they can be applied in more complex molecules*

## Naming Alkanes





*This activity deals with how to name branched alkanes using systematic names, i.e. names that follow a very definite system which is based on the structure of the molecule.*

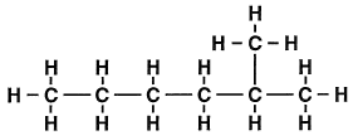
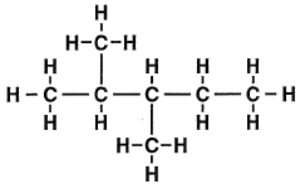
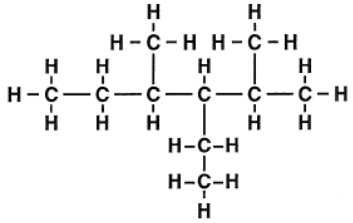
In a ***straight-chain*** *hydrocarbon*, all the ***carbon*** atoms in the molecule are linked one after the other in a ***single*** continuous chain.

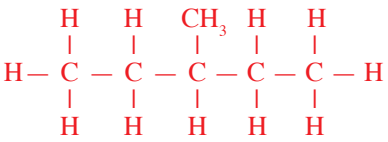
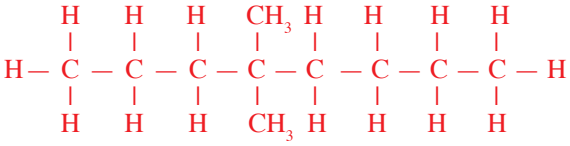
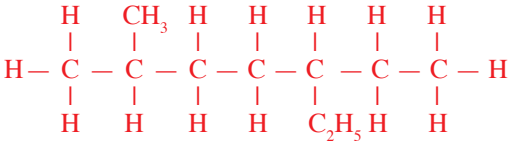
In a ***branched-chain*** *hydrocarbon*, the molecule has one or more ***side chains*** of carbon atoms off the main chain.

Due to ***branching***, it is possible to have *different* ***structural*** arrangements for the *same* ***molecular*** *formula*. ***Butane***, $C_4H_{10}$, has two *different* structures called ***isomers***. Clearly both of them cannot have *exactly* the same name.

***Naming Rules for Alkanes***

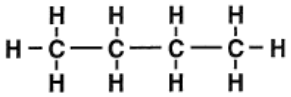
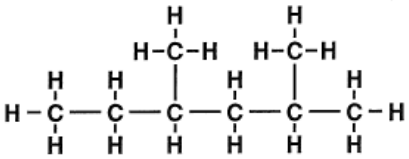
1. The ***longest chain*** defines the main chain and the last part of the name
2. ***Numbering*** of the main chain starts from the end that gives the lower overall number positions for side branches
3. ***Side branch*** names end in ***'-yl'*** and depend on the number of carbon atoms in them: *methyl* for 1 carbon, *ethyl* for 2 carbon atoms, *propyl* for 3 carbon atoms, etc.
4. ***Alphabetical*** order is used if different side branches appear in the same structure (*ethyl* before *methyl*).
5. ***Hyphens*** are used before or after numbers that come next to letters within a name (2-ethyl-3-methyl..)
6. ***Commas*** are used between numbers showing more than one of the same side branch (2,2,3-trimethyl..)

| *Full structural formula* | *Systematic name* |
|---|---|
|  | 2-methylhexane |
|  | 2,3-dimethylpentane |
|  | 3-ethyl-2,4-dimethylhexane |

| *Systematic name* | *Full Structural formula* |
|---|---|
| 3-methylpentane |  |
| 4,4-dimethyloctane |  |
| 5-ethyl-2-methylheptane |  |

## *Shortened Structural Formulae*

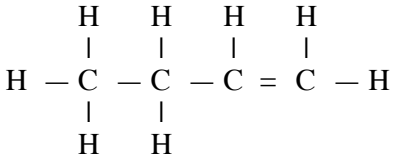
*This activity is about writing and using shortened structural formulae for alkanes*

| *Full Structural Formula* | *Shortened Structural Formula* |
|---|---|
|  | $CH_3CH_2CH_2CH_3$ |
|  | $CH_3CH_2CH(CH_3)CH_2CH(CH_3)CH_3$ |
| ***Shortened Structural Formula*** | ***Systematic Name*** |
| $CH_3CH_2CH(CH_3)CH_2CH_2CH_3$ | 3-methylheptane |
| $CH_3CH(CH_3)CH_2CH_2CH(CH_3)CH_2CH_3$ | 3-ethyl-2,4-dimethylhexane |

| *Systematic Name* | *Shortened Structural Formula* |
|---|---|
| 3-methylpentane | $CH_3CH_2CH(CH_3)CH_2CH_3$ |
| 2,4-dimethylhexane | $CH_3CH_2CH(CH_3)CH_2CH(CH_3)CH_3$ |

## Branched Alkenes

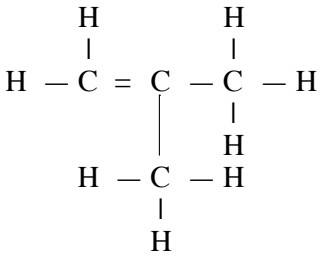
*This activity considers how to use systematic names to indicate both the positions of side branches and the position of the double bond in the alkene structure.*



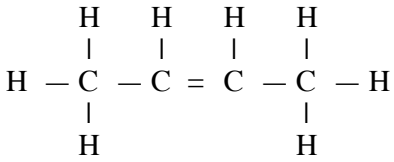
**but-1-ene**

There are even more ***isomers*** possible in the *alkene* family. Again there are ***straight****-chain alkenes* and ***branched****-chain alkenes*.

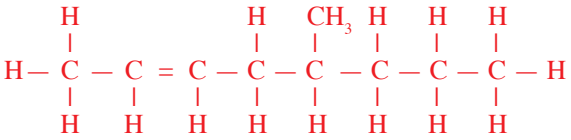
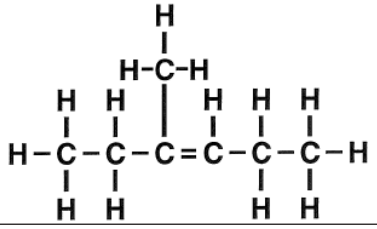
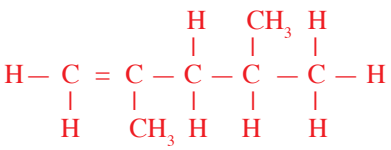
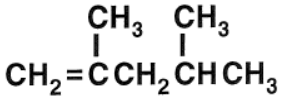
In addition, it is possible to change the ***position*** of the ***double*** *bond* to introduce even more *different* ***structural*** *formulae*.



**2-methylprop-1-ene**

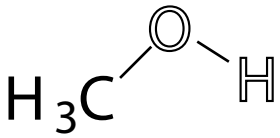


**but-2-ene**

| Branched Alkene Structures | |
|---|---|
| *Name:* | 5-methyloct-2-ene |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH=CHCH_2CH(CH_3)CH_2CH_2CH_3$ |
| *Name:* | 3-methylhex-3-ene |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2C(CH_3)=CHCH_2CH_3$ |
| *Name:* | 2,4-dimethylpent-1-ene |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* |  |

## Alkanols

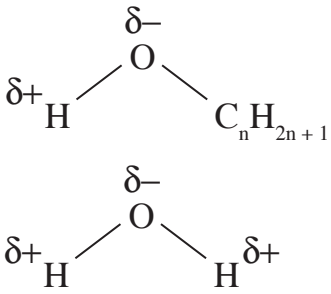
*This activity revises the alkanol family*



$C_n H_{2n+1} OH$

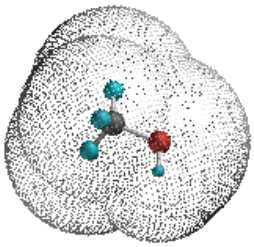
The ***functional group*** in alkanols is the ***Hydroxyl*** *group*.

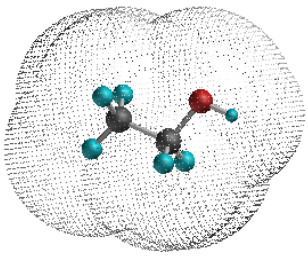
The ***alkanols*** can be thought of as '*substituted alkanes*' - a ***hydrocarbon*** chain with the ***hydroxyl*** *group* replacing one of the ***hydrogen*** atoms.

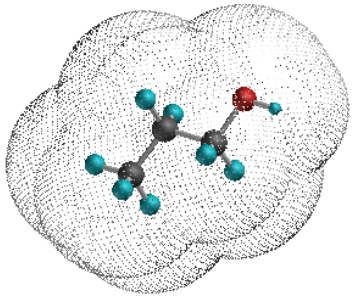


Like ***water***, *alkanols* are ***covalent*** molecules and, as a result, are *very poor* ***conductors*** of electricity.

Like ***water***, *alkanols* have a ***polar*** O—H bond which allows ***hydrogen*** *bonding* between molecules. As a result, water and smaller alkanols will '*dissolve*' in each other as the ***strength*** of their *intermolecular* forces are very ***similar***.





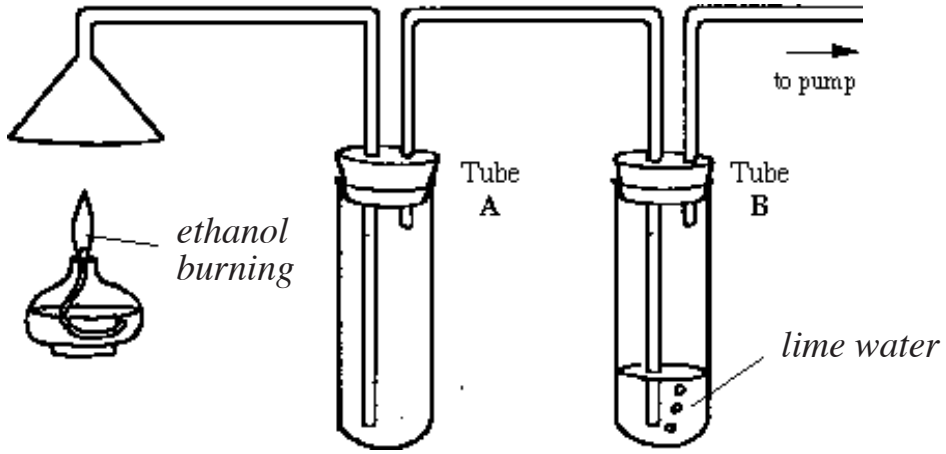


As well as sharing the same ***General formula***, the ***physical*** *properties* of the alkanols such as *melting point* (***increases***), *boiling point* (***increases***) and *solubility in water* (***decreases***) show a steady trend as the *molecular size* increases. For these reasons, the alkanols can be described as a ***homologous series***.

| *Property* | *Result* |
|---|---|
| *Appearance* | ***colourless liquids*** |
| *Solubility* | ***smaller alkanols are very soluble*** |
| *pH* | ***neutral, do not produce $H^+$ or $OH^-$ ions in water*** |
| *Conduction* | ***covalent, so non-conductors*** |
| *Burning* | ***burn to produce $CO_2$ and $H_2O$*** |

## Combustion of Ethanol

*This activity is about the products of combustion reaction of ethanol*




***ethanol*** + ***oxygen*** → ***carbon dioxide*** + ***water***

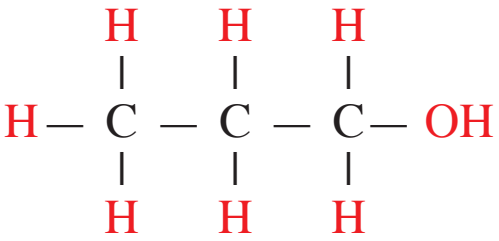
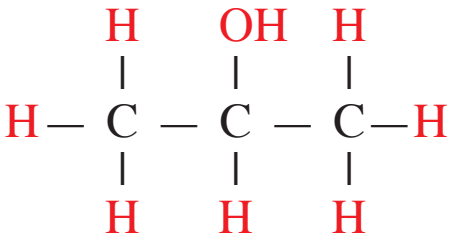
$$2\,C_2H_5OH + 5\,O_2 \rightarrow 4\,CO_2 + 6\,H_2O$$

The ***combustion*** of ethanol can be referred to as ***oxidation*** on the basis that the ***carbons*** and ***hydrogens*** are ' *gaining oxygen* '. Later in this topic *mild oxidation* of alcohols will lead to totally different, and much more important, products - ***aldehydes***, ***ketones*** and ***carboxylic acids***.

## Straight-Chain Alkanols

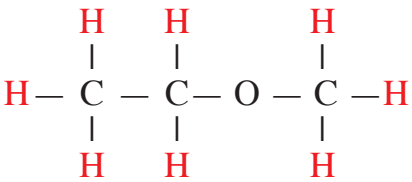
*This activity considers how to use systematic names to indicate the position of the hydroxyl group in isomers*

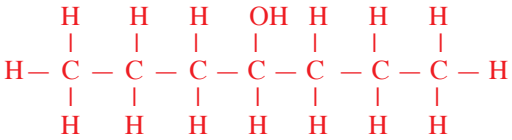
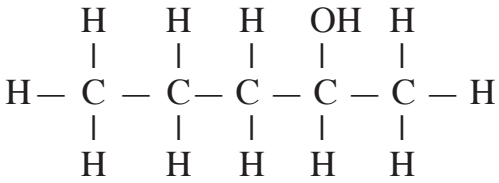
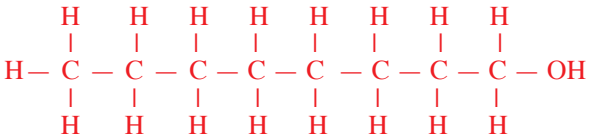
The position of the *hydroxyl* group can change to produce *isomers* without the need to introduce branches.

| | | |
|---|---|---|
| ***Full Structural*** |  |  |
| ***Shortened Structural*** | $CH_3CH_2CH_2OH$ | $CH_3CH(OH)CH_3$ |
| ***Systematic Name*** | propan-1-ol | propan-2-ol |

$C_3H_6O$

*Isomers* don't have to be from the same homologous series



| *Straight-Chain Alkanols* | |
|---|---|
| *Name:* | heptan-4-ol |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2CH_2CH(OH)CH_2CH_2CH_3$ |
| *Name:* | pentan-2-ol |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2CH_2CH(OH)CH_3$ |
| *Name:* | octan-1-ol |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH$ |

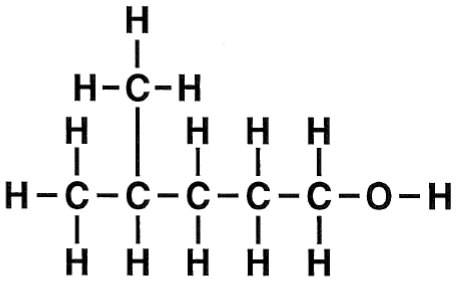
## *Branched-Chain Isomers*

*This activity considers how to use systematic names to indicate both the position of the hydroxyl group and the branch position in isomers of branched-chain alkanols*

***The 'longest chain' must include the functional group.***

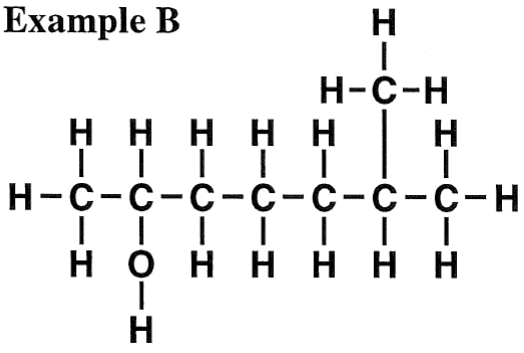
***The chain is numbered from the end nearest the functional group***

**Example A**

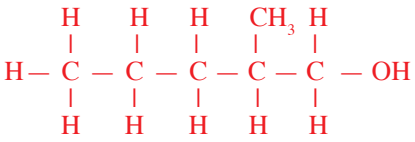
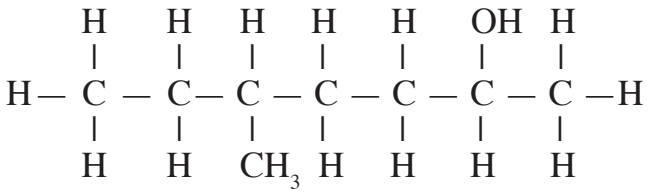
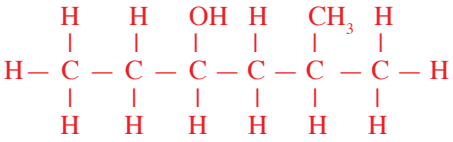
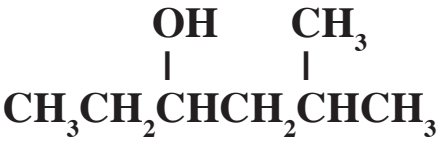


***2-methylpentan-1-ol***

**Example B**

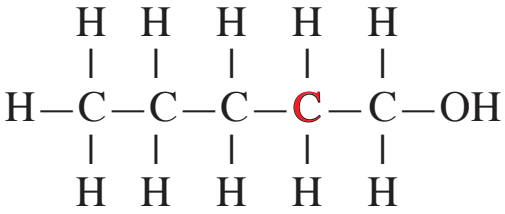


***6-methylheptan-2-ol***

| ***Branched-Chain Alkanols*** | |
|---|---|
| *Name:* | 2-methylpentan-1-ol |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2CH_2CH(CH_3)CH_2OH$ |
| *Name:* | 5-methylheptan-2-ol |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2CH(CH_3)CH_2CH_2CH(OH)CH_3$ |
| *Name:* | 4-methylhexan-3-ol |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* |  |

## *Primary, Secondary & Tertiary*

*This activity relates the classification of alcohols to their molecular structures*

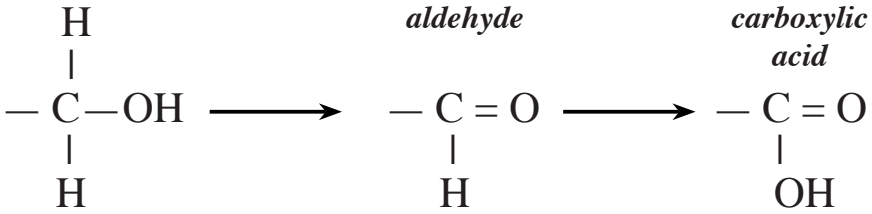


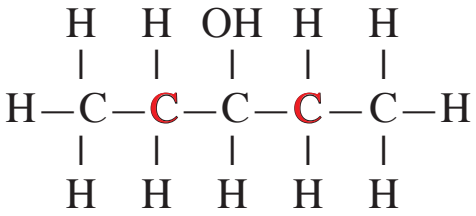
This is an example of a ***primary alcohol***.

It is so-called because only ***one carbon*** is directly attached to the carbon with the ***hydroxyl*** *group*.

The ***hydroxyl*** *group* is at the ***end of the chain***.

***Systematic Name*** ***pentan-1-ol***

***mild oxidation :*** ***primary alcohol***  ***aldehyde*** ***carboxylic acid***

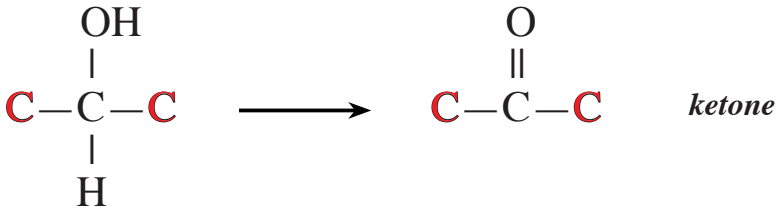


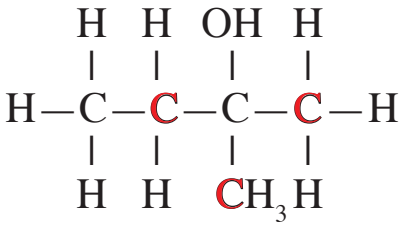
This is an example of a ***secondary alcohol***.

It is so-called because ***two carbons*** are directly attached to the carbon with the ***hydroxyl*** *group*.

The ***hydroxyl*** *group* is ***along the chain***.

***Systematic Name*** **pentan-3-ol**

***mild oxidation :*** ***secondary alcohol***  ***ketone***

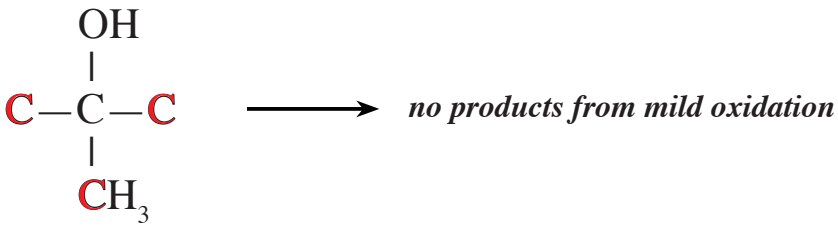


This is an example of a ***tertiary*** alcohol.

It is so-called because ***three carbons*** are directly attached to the carbon with the ***hydroxyl*** *group*.

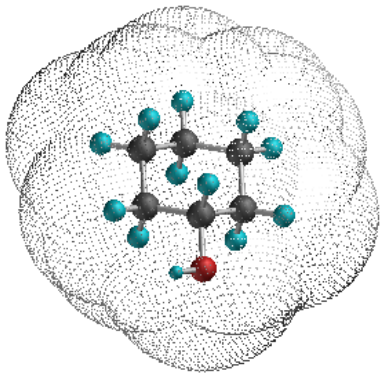
The ***hydroxyl*** *group* is at ***a branched position*** of the chain.

***Systematic Name*** **2-methylbutan-2-ol**

***mild oxidation :*** ***tertiary alcohol***  ***no products from mild oxidation***

## *Ring Structures*

*This activity looks briefly at the structures and names of the cyclalkanols*



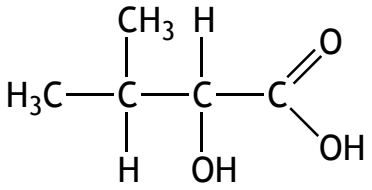
| | | |
|---|---|---|
| ***Molecular Formula*** | $C_4H_7OH$ | $C_5H_9OH$ |
| ***Full Structural*** | | |
| ***Systematic Names*** | | |

*Cycloalkanols* are examples of ***secondary*** alcohols because there are ***two carbons*** attached to the carbon with the ***hydroxyl*** *group* - the hydroxyl group is 'along the chain'.

*Cycloalkanols* are ***not isomers*** of *alkanols*, because there are ***two less hydrogens*** in a ring structure compared to the equivalent chain structure.

## Hydroxyl Group as Substituent

*This activity demonstrates how the hydroxyl group is named in molecules with more important groups present.*



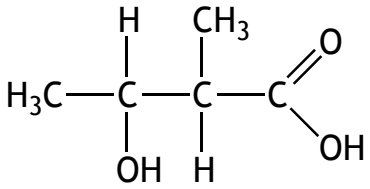
In this molecule the ***carboxylic*** acid group, —COOH, is ***more important*** and the presence of the —OH is signified by the use of the *prefix* '***hydroxy***' rather than the normal *suffix* '***-ol***'

***2-hydroxy-3-methylbutanoic acid***

Other groups that you might meet as suffixes:-

$—NH_2$ ***amine*** becomes ***amino***

—COOH ***carboxylic*** becomes ***carboxyl***



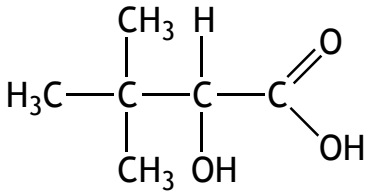
***3-hydroxy-2-methylbutanoic acid***

You are already familiar with:-

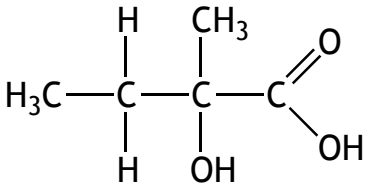
$CH_4$ ***methane*** becoming ***methyl***

But may also see:-

$—O—CH_3$ becoming ***methoxy***



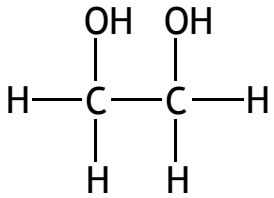
***2-hydroxy-3,3-dimethylbutanoic acid***



***2-hydroxy-2-methylbutanoic acid***

## More Than One Hydroxyl Group

*This activity looks at the structures and names of two alcohols which have more than one hydroxyl group*

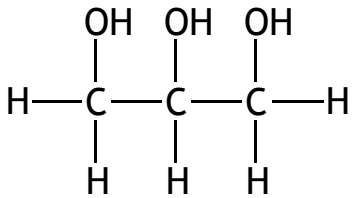


***ethane-1,2-diol***

The common name for this alcohol is ***glycol*** .

It is used as ***antifreeze*** in car ***radiators***.

It contains *two* ***hydroxyl*** *group* and can be referred to as a ***dihydric*** alcohol or a ***diol***.



***propane-1,2,3-triol***

The common name for this alcohol is ***glycol*** .

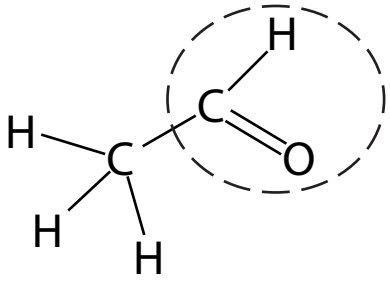
It has various culinary uses including ***ice-cream***

It contains *three* ***hydroxyl*** *group* and can be referred to as a ***trihydric*** alcohol or a ***triol***.

## Aldehyde Structures

*This activity considers the structures and systematic names of the alkanal series of aldehydes.*

*An **alkanal** is a compound which contains the **carbonyl** group at the end position of a hydrocarbon chain in which all the carbon atoms are linked by single bonds.*

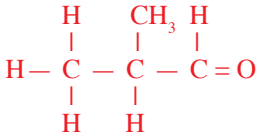
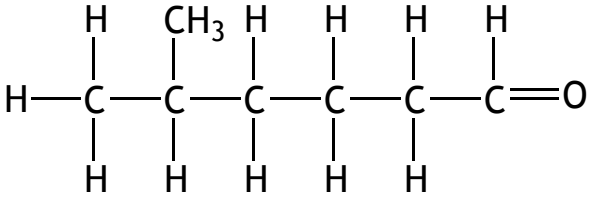
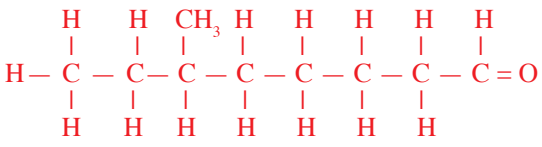



The ***functional*** *group* of an aldehyde contains the ***carbonyl*** *group* and a ***hydrogen*** atom - —CHO.

$CH_3CHO$

The longest carbon chain includes the ***functional*** *group*, so this molecule is named as ***ethanal***.

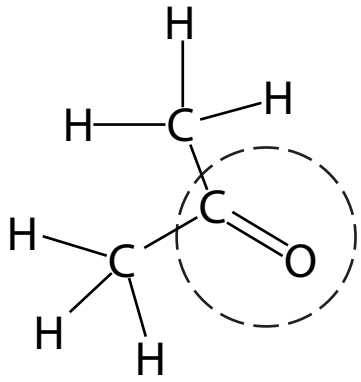
The chain is always numbered from the end with the —CHO functional group.

| ***Alkanal Structures*** | |
|---|---|
| *Name:* | 2-methylpropanal |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH(CH_3)CHO$ |
| *Name:* | 5-methylhexanal |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH(CH_3)CH_2CH_2CH_2CHO$ |
| *Name:* | 6-methyloctanal |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2CH(CH_3)CH_2CH_2CH_2CHO$ |

## Ketone Structures

*This activity considers how to apply systematic names to the alkanone family of ketones.*

*An **alkanone** is a compound which contains the **carbonyl** group at a position within a hydrocarbon chain where all the carbon atoms are linked by single bonds.*

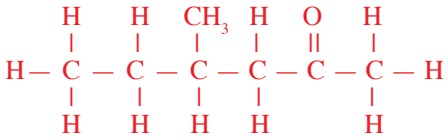
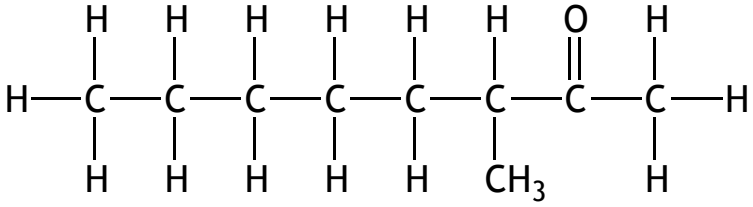
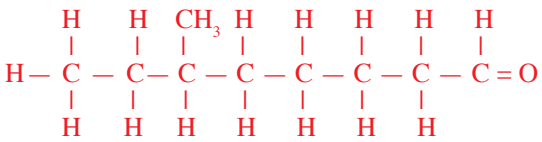


The ***functional*** *group* of a ketone is simply the ***carbonyl*** *group* by itself.

$CH_3COCH_3$

The longest carbon chain must include the ***functional*** *group*. This molecule is named as ***propanone***.

The chain is always numbered from the end nearest the —CO— functional group.

| ***Alkanone Structures*** | |
|---|---|
| *Name:* | 4-methylhexan-2-one |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3\,CH_2\,CH\,(CH_3)\,CH_2\,CO\,CH_3$ |
| *Name:* | 3-methyloctan-2-one |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3\,CH_2\,CH_2\,CH_2\,CH\,(CH_3)\,CO\,CH_3$ |
| *Name:* | 4-methylhexan-3-one |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2CHCOCH_2CH_3$ (CH$_3$ branch on the CH) |

## Alkanoic acids

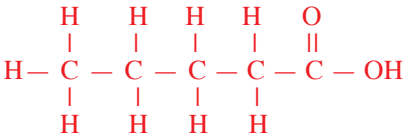
*This activity considers the structures, formulae and systematic names of some of the members of the alkanoic acid family.*

Any molecule that contains the *carboxyl group*, —COOH, can be considered as a *carboxylic acid*. The molecule could have a ***chain*** structure, a ***ring*** structure, it could be ***saturated*** (C—C) or ***unsaturated*** (C=C or C≡C).

*The **alkanoic acids** are compounds which contain the **carboxyl group** joined to a hydrocarbon **chain** in which all the carbon atoms are joined by **single** bonds.*

As usual, there are three ways to represent the formula of, for example, *pentanoic acid*

*full structural formula*



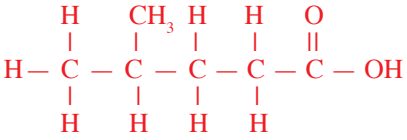
*shortened structural formula*

$CH_3CH_2CH_2CH_2COOH$

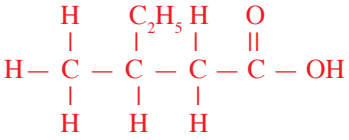
*functional molecular formula*

$C_4H_9COOH$

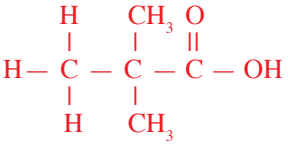
For naming purposes, the ***carbon*** of the ***carboxyl functional*** *group* is always taken as number 1, and the *'longest'* chain always starts with the ***functional*** *group*. For example:



***4-methylpentanoic acid***



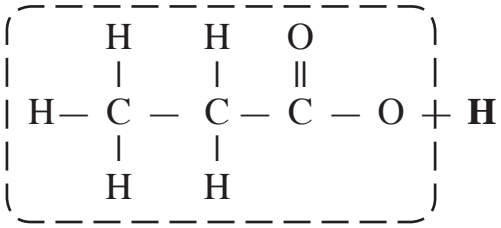
***2-ethylbutanoic acid***



***2,2-dimethylpropanoic acid***

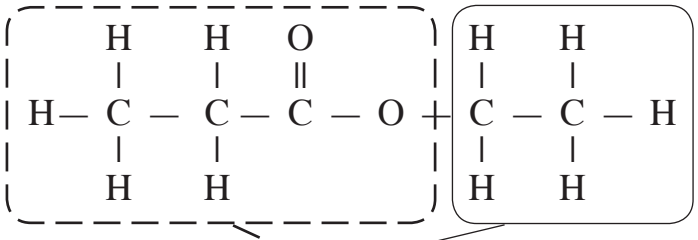
## Simple Esters

*This activity deals with naming and drawing full and structural formulae for esters.*



The 'best'way to think about an ***ester*** is to consider it as an ***acid molecule*** which has had its ***hydrogen atom*** replaced by a ***carbon chain*** ( an *alkyl group*).

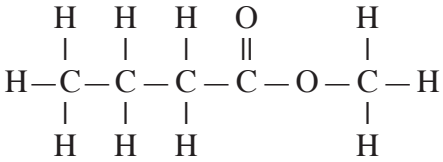
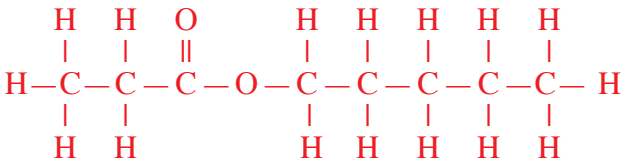
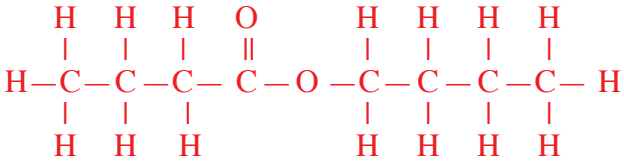
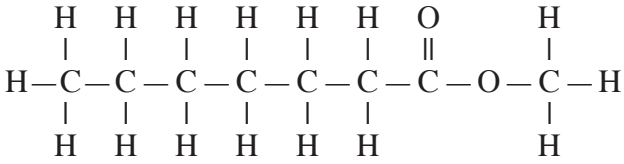
*Learn to draw acids and you should find esters easy.*



***ethyl propanoate***

As is often the case, we 'start' at the end of the name. *Identify the acid* (look for the ***carbonyl*** C = O) and give the ***ester*** its ***surname*** by changing the *—oic* ending to ***—oate***.

The *carbon chain* (derived from the parent ***alcohol***) is the ***'christian' name***, *—ol* changed to ***—yl***.

| *Ester Structures & Names* | |
|---|---|
| *Name:* | ***methyl butanoate*** |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2CH_2COOCH_3$ |
| *Name:* | pentyl propanoate |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2COOCH_2CH_2CH_2CH_2CH_3$ |
| *Name:* | ***butyl butanoate*** |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2CH_2COOCH_2CH_2CH_2CH_3$ |
| *Name:* | ***methyl heptanoate*** |
| *Full Structural Formula:* |  |
| *Shortened Structural Formula:* | $CH_3CH_2CH_2CH_2CH_2CH_2COOCH_3$ |