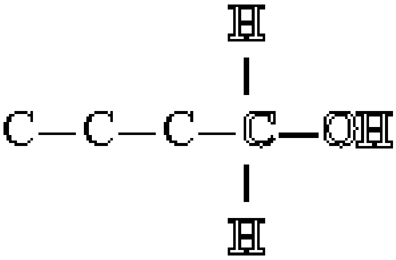
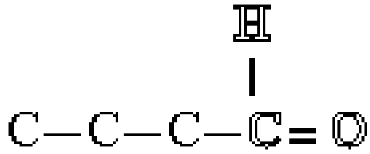
Higher Chemistry



Unit 2: The World of Carbon



Section 6:

Alcohols & Carbonyls

Student:

Lesson		Activities		Done	Checked
6.1 ***Common Alcohol***	1.	Properties Of Ethanol			
	2.	Structures OF Ethanol			
	3.	Combustion Of Ethanol			
		Check Test	Score: /		
		Home Practice	Score: /		
6.2 ***Industrial Ethanol***	1.	Manufacture Of Ethanol			
	2.	Uses Of Ethanol			
	3.	Ethanol As A Feedstock			
		Check Test	Score: /		
		Home Practice	Score: /		
6.3 ***Alkanol Family***	1.	Homologous series			
	2.	Straight-Chain Isomers			
	3.	Branched-Chain Isomers			
		Check Test	Score: /		
		Home Practice	Score: /		
6.4 ***Alcohol Structures***	1.	Primary, Secondary, & Tertiary			
	2.	Ring Structures			
	3.	More Than One Hydroxyl			
		Check Test	Score: /		
		Home Practice	Score: /		
6.5 ***Oxidising Alcohols***	1.	Comparing Oxidation			
	2.	The Oxidation Reaction			
	3.	Oxidising With Copper(II) Oxide			
		Check Test	Score: /		
		Home Practice	Score: /		
6.6 ***Aldehydes & Ketones***	1.	Aldehyde Structures			
	2.	Ketone Structures			
	3.	Distinguishing Tests (PPA)			
		Check Test	Score: /		
		Home Practice	Score: /		
6.7 ***Methanol & Methanal***	1.	Synthesis Gas			
	2.	Manufacturing Methanol			
	3.	Manufacturing Methanal			
		Check Test	Score: /		
		Home Practice	Score: /		
Consolidation Work		Consolidation A	Score: /		
		Consolidation B	Score: /		
		Consolidation C	Score: /		
		Consolidation D	Score: /		
End-of-Section Assessment		Score: %	Grade:		

Notes	*Revision Questions Questions*	*Text Book*
6.1 Common Alcohol		
Properties of Ethanol		
Structures of Ethanol		
Combustion of Ethanol		
6.2 Industrial Ethanol		
Manufacture of Ethanol	p70 Ex 2.8 Q10	
Uses of Ethanol		
Ethanol as a Feedstock	p69 Ex 2.8 Q9	
6.3 Alkanol Family		
Homologous Series		
Straight-Chain Isomers		
Branched-Chain Isomers	p61 Ex 2.8 Q1 - 5	p81 Q1-3
6.4 Alcohol Structures		
Primary, Secondary & Tertiary	p71 Ex 2.9 Q1-3	
Ring Structures		
More than one Hydroxyl		
6.5 Oxidising Alcohols		
Comparing Oxidation		
The Oxidation Reaction	p72,73 Ex 2.10 Q1 - 8	
Oxidising with Copper (II) oxide		
6.6 Aldehydes & Ketones		
Aldehyde Structures		
Ketone Structure	p62 Ex 2.4 Q1 - 3, 7, 9, 10	p84 Q4
Distinguishing Tests (PPA)		
6.7 Methanol & Methanal		
Synthesis Gas		
Manufacturing Methanol		
Manufacturing Methanal		
Consolidation Work	*Text Book p87 Study Questions*	

UNIT 2. THE WORLD of CARBON

Section 6: Alcohols & Carbonyls

Alcohols

1. *An alcohol can be identified from the **hydroxyl** functional group and the '**-ol**' name ending*

   hydroxyl group = —O—H or —OH
   (it is **not** a hydroxide ion! alcohols are **not** alkalis!)

2. ***Alkanols** are a homologous series of alcohols based on the corresponding parent alkanes*

   methane, CH_4 → methanol, CH_3OH
   ethane, C_2H_6 → ethanol, C_2H_5OH

3. *Systematic names, full and shortened structural formulae can be used for straight- and branched- chain alkanols (C_1 to C_8)*

   butan-1-ol, butan-2-ol, 2,methylpropan-1-ol

4. *Alcohols can be classified as **primary**, **secondary** or **tertiary***

   primary, OH at end of chain, butan-1-ol
   secondary, OH in middle of chain, butan-2-ol
   tertiary, middle of chain with a branch at ***same*** place, 2,methylpropan-2-ol

5. *Alcohols burn in oxygen and air to produce carbon dioxide and water*

   $C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$
   (covered in Unit 1; enthalpy of combustion)

6. *To meet market demand ethanol is made by means other than fermentation*

   In previous section on Fuels

7. *Direct **catalytic hydration** of alkenes is another way of making alkanols*

   In previous section on Hydrocarbons as the ***addition*** of H_2O to an alkene

8. *Alkanols can be converted to alkenes by **dehydration***

   Also useful as a means of making ***specific*** alkenes

9. *Primary and secondary alcohols can be **oxidised** by a number of **oxidising agents**, including **copper(II)oxide** and **acidified potassium dichromate** solution*

   $Cu^{2+} + 2e \rightarrow Cu$ *reduction*
   $Cr_2O_7^{2-} + 14H^+ + 6e \rightarrow 2Cr^{3+} + 7H_2O$
   (acid is added to provide H^+) *reduction*

10. *Primary alcohols are **oxidised**, first to **aldehydes** and then to **carboxylic acids***

    (end of chain) C—OH → C = O → COOH

11. *Secondary alcohols are **oxidised** to **ketones***

    (middle of chain) C—OH → C = O

12. *When applied to carbon compounds, **oxidation** results in an **increase** in the **oxygen to hydrogen ratio***

    (The 'reverse' relationship is not necessarily true: the reaction $H_2O + C_2H_4 \rightarrow C_2H_5OH$, would increase the O:H ratio but this is *addition* or *hydration*, **not** *oxidation*)

    In Biology this equates to *oxidation → loss of H*

Aldehydes & Ketones

14. *An aldehyde and a ketone can be identified from the **carbonyl** group , and the '**-al**' and '**-one**' name endings*

Carbonyl group = —C = O
(***aldehyde*** has group ***at end***, *ketone* in *middle*, of chain)

15. ***Alkanals*** *are a homologous series of aldehydes based on the corresponding parent alkane*

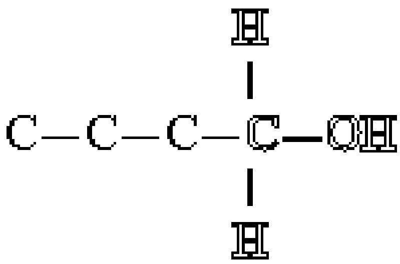
methane, CH_4 → methanal, $H_2C{=}O$
ethane, C_2H_6 → ethanal, $CH_3HC{=}O$

16. ***Alkanones*** *are a homologous series of ketones based on the corresponding parent alkane*

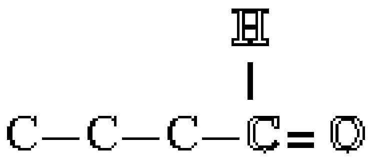
propane, $CH_3CH_2CH_3$ → propanone, CH_3COCH_3
butane, $CH_3CH_2CH_2CH_3$ → butanone, $CH_3CH_2COCH_3$

17. *Systematic names, full and shortened structural formulae can be used for straight- and branched- chain alkanals and alkanones (C_1 - C_8)*

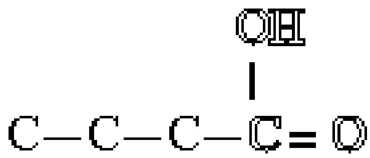
butanal, methylpropanal, pentan-2-one, pentan-3-one



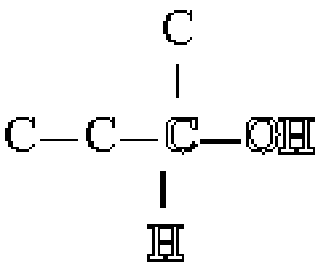
a ***primary*** *alkanol*
(—OH at end of chain)
butan-1-ol



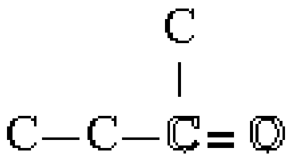
an *alkanal*
(C=O at end of chain)
butan-1-al



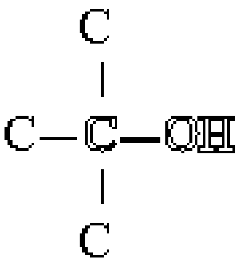
an *alkanoic acid*
(COOH at end of chain)
butanoic acid



a ***secondary*** *alkanol*
(—OH in middle of chain)
butan-2-ol



a *alkanone*
(C=O in middle of chain)
butan-2-one



a ***tertiary*** *alkanol*
(—OH at same place as a branch)
2,methylpropan-2-ol

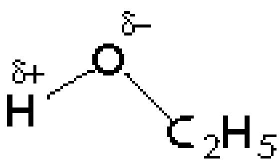
6.1 Common Alcohol

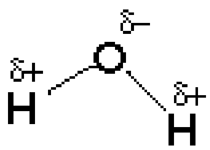
This Section is about alcohols and another group of related compounds, the carbonyls. This first lesson is about ethanol, the most common of all alcohols.

Properties of Ethanol

The aim of this activity is to investigate some of the properties of ethanol

Property	*Result*
Appearance	
Solubility	
pH	
Conduction	
Burning	



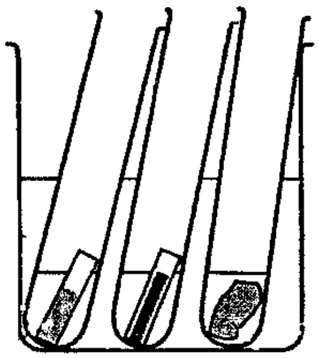


Like **wa** , *ethanol* is a ***cov*** molecule and, as a result, is a *very poor* ***cond*** of electricity.

Like **wa** , *ethanol* has a ***pol*** O—H bond which allows ***hyd*** *bonding* between molecules. As a result, water and ethanol will '*dissolve'* in each other as the ***stre*** of their *intermolecular* forces are very ***sim*** .

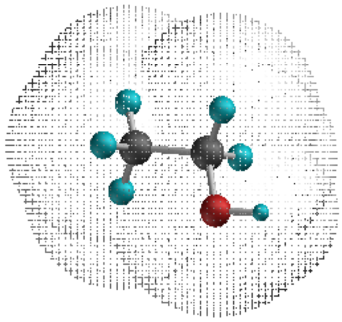
Like ***wa*** , ethanol is an excellent ***solv*** able to ***diss*** a variety of substances.

Ethanol is widely used as the ***solv*** for many ink based pens and is, therefore, the ideal chemical to be used when attempting to remove ink stains.

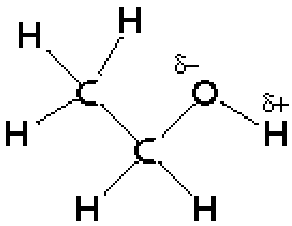


Structure of Ethanol

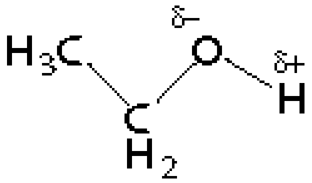
This activity examines the structure and formula of ethanol



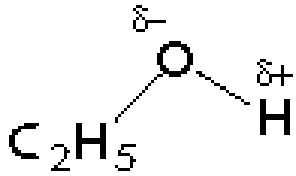
Ethanol has a short ***hy*** ***car*** chain, like an ***alk*** , with the ***hydr*** *functional group* at the end.



Full Structural Formula



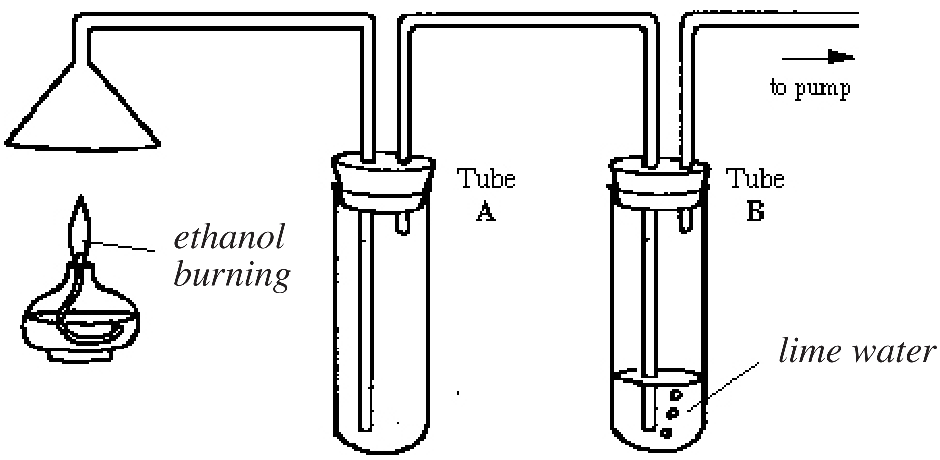
Shortened Structural Formula



Functional Molecular Formula

Combustion of Ethanol

This activity is about the products of combustion reaction of ethanol



Word equation: + → +

Formulae equation: + → +

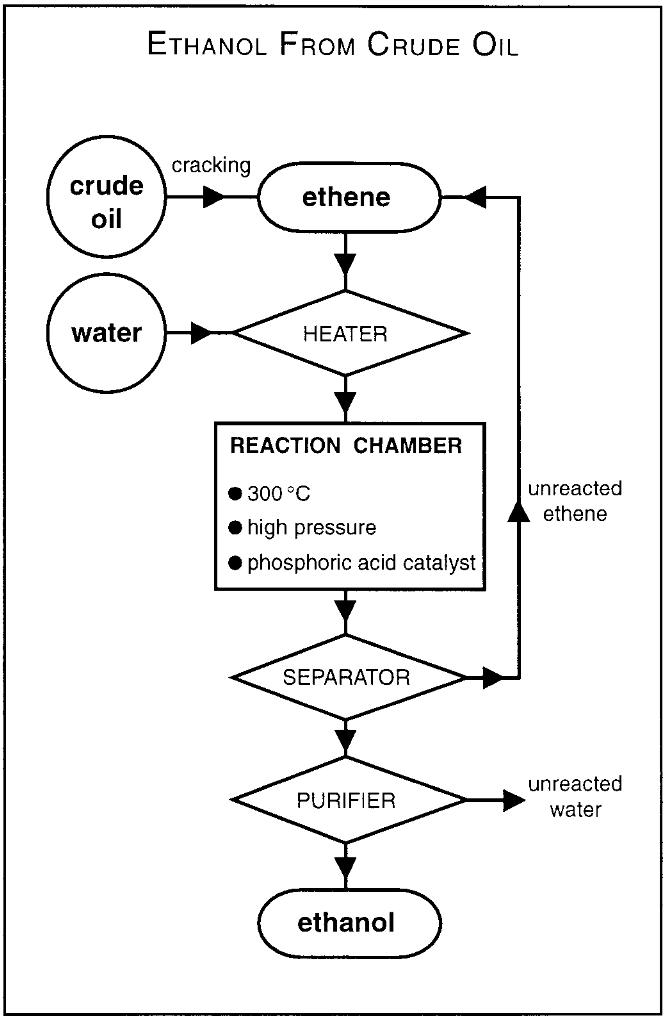
The ***comb*** of ethanol can be referred to as ***oxi*** on the basis that the ***car*** and ***hydr*** are ‘ *gaining oxygen* ’. Later in this topic *mild oxidation* of alcohols will lead to totally different, and much more important, products.

6.2 Industrial Ethanol

This second topic looks at ethanol as an industrial chemical.

Manufacture of Ethanol

This activity outlines the two main processes for manufacturing ethanol



The two main processes for the manufacture of ethanol are ***ferm*** of ***car hyd*** and the hydration of ***eth*** , obtained from ***cr oil***.

Though ***ferm*** takes place on an industrial scale, it is mainly concerned with the production of ***alc*** drinks. ***Hydr*** is the cheaper option for making industrial ethanol.

Fermentation

→ +

Hydration

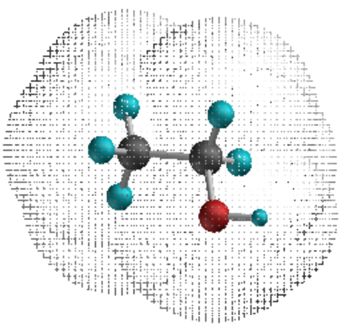
+ →

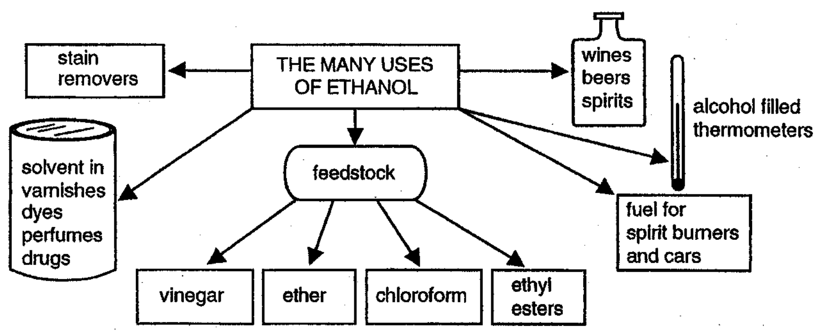
Hydr was first met in the last Section as the ***add*** of water to ***alk*** .

A **Hydr** *reaction is any reaction in which the elements of water are added to a substance.*

Uses of Ethanol

This activity outlines some of the many uses of ethanol





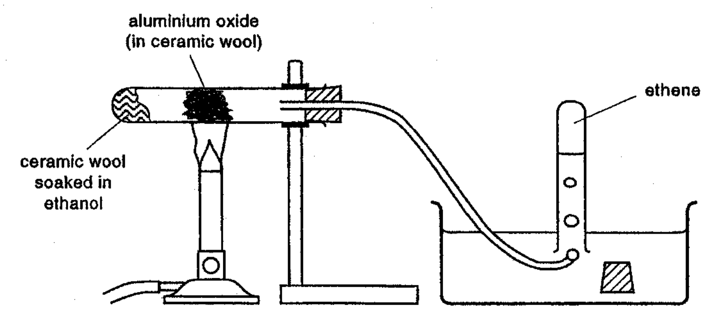
Uses of Ethanol				
drinks	***solvent***	***fuel***	***low MPt liquid***	***feedstock***

Eth   , unlike ***pet***   , can be considered a ***ren***   ***fuel*** because it can be made fom sources of ***car***   ***hyd***   , such as *sugar cane*, which can be *grown again each year*.

Ethanol As A Feedstock

This activity describes how ethanol can be converted into ethene

Eth   is the most important *feedstock* for the ***plas***   industry. At the moment the ***eth*** is obtained from ***cr***   ***oil***, but when *oil runs out* ***eth***   , produced by ***ferm***   , will become an important alternative source of ethene.



The catalyst, aluminium oxide, is heated and ethanol vapour passes over it.

The ethene produced is collected by bubbling through water.

Word Equation

$\rightarrow$

Formula Equation

$\rightarrow$

*A **dehydration** reaction is any reaction in which the elements of water are removed from a substance*

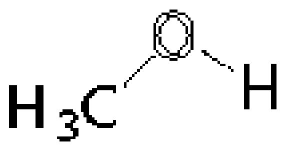
6.3 Alkanol Family

This lesson introduces the structures and names of members of the alkanol family.

Homologous Series

This activity examines the names and structures of simple straight-chain alkanols

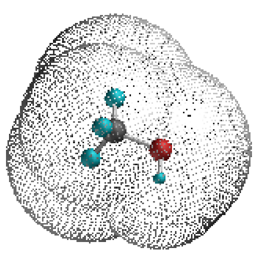
Name	*Functional Molecular Formula*	*Full Structural Formula*

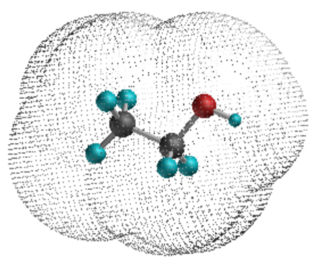


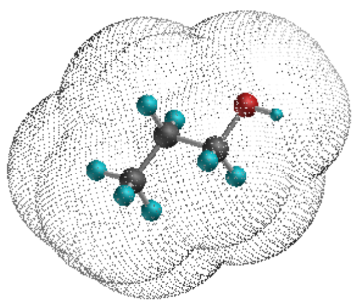
The ***func*** ***group*** in alkanols is the ***Hydr*** *group*.

C_nH OH

The ***alk*** can be thought of as '*substituted alkanes*' - a ***hydroc*** chain with the ***hydr*** *group* replacing one of the ***hydr*** atoms.







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

Straight-Chain Isomers

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

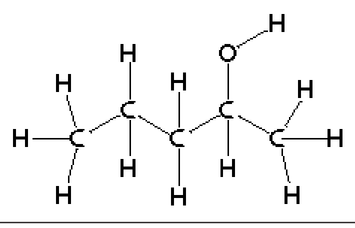
The position of the hydroxyl group can change to produce isomers without the need to introduce branches.

Full Structural

— C — C — C —   — C — C — C —

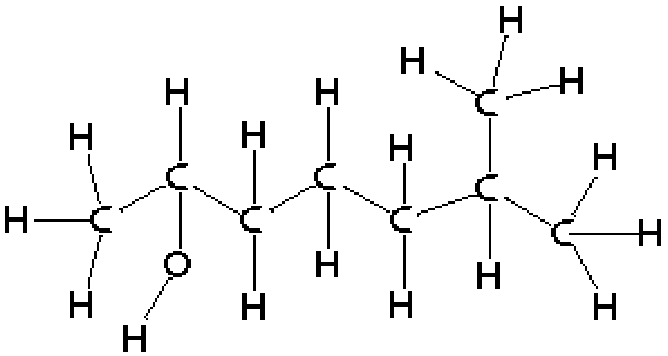
Shortened Structural

Systematic Name

Straight-Chain Alkanols	
Name:	heptan-4-ol
Full Structural Formula:	
Shortened Structural Formula:	
Name:	
Full Structural Formula:	
Shortened Structural Formula:	
Name:	
Full Structural Formula:	
Shortened Structural Formula:	$\mathbf{CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH}$

Branched-Chain Isomers

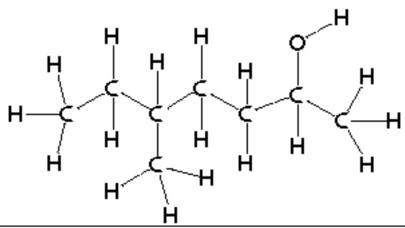
This activity considers how to use systematic names to indicate both the position of the hydroxyl group and the branch position in isomers of branched-chain alkanols



The 'longest chain' must include the functional group.

The chain is numbered from the end nearest the functional group

Systematic Name

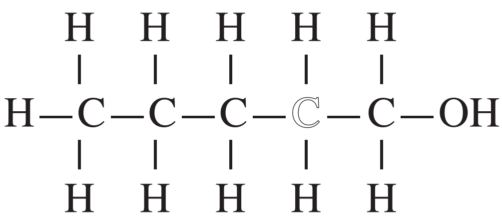
Branched-Chain Alkanols	
Name:	2-methylpentan-1-ol
Full Structural Formula:	
Shortened Structural Formula:	
Name:	
Full Structural Formula:	
Shortened Structural Formula:	
Name:	
Full Structural Formula:	
Shortened Structural Formula:	OH (on C3), CH_3 (on C5): $CH_3CH_2CHCH_2CHCH_3$

6.4 Alcohol Structures

This lesson looks in more detail at a variety of alcohol structures

Primary, Secondary & Tertiary

This activity relates the classification of alcohols to their molecular structures

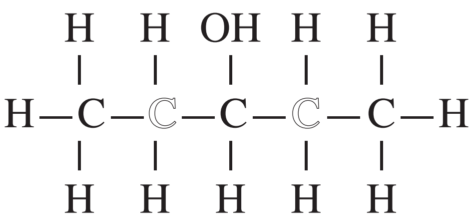


This is an example of a ***prim*** ***alcohol***.

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

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

Systematic Name

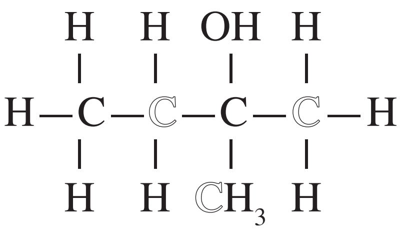


This is an example of a ***sec*** ***alcohol***.

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

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

Systematic Name



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

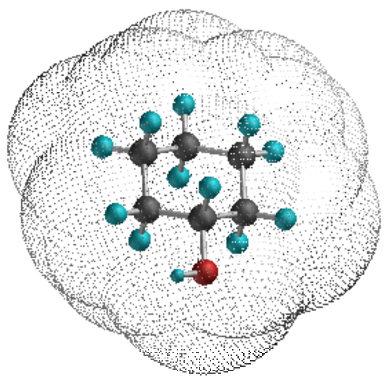
It is so-called because ***three car*** are directly attached to the carbon with the ***hyd*** *group*.

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

Systematic Name

Ring Structures

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



Full Structural

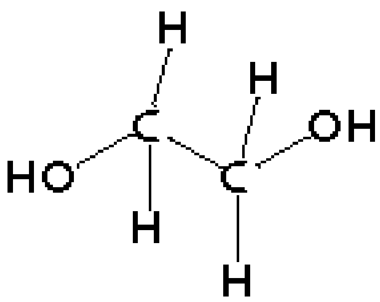
Systematic Names

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

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

More Than One Hydroxyl Group

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

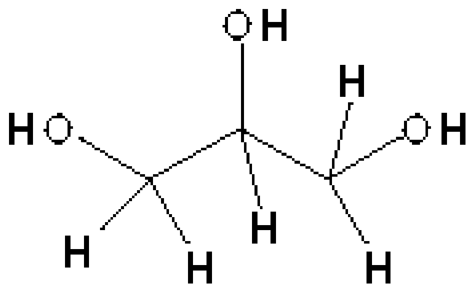


The common name for this alcohol is ***gly*** .

It is used as ***anti*** in car ***rad*** .

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

Systematic Name



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

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

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

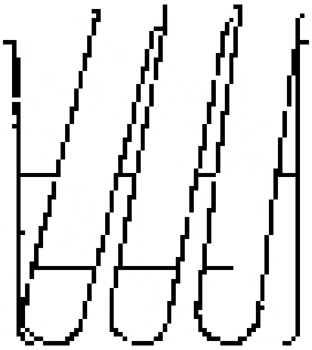
Systematic Name

6.5 Oxidisng Alcohols

This topic examines how the different types of alcohol are oxidised and the different types of product produced.

Comparing Oxidation

This activity compares the oxidation reactions of the three types of alcohol



Aci *potassium* **dichr** is a mild *oxidising agent* that *changes* ***col*** when it reacts.

Three different *types* of alcohol were added to some *dichromate* solution and placed in a hot ***wa*** *bath* for a few minutes.

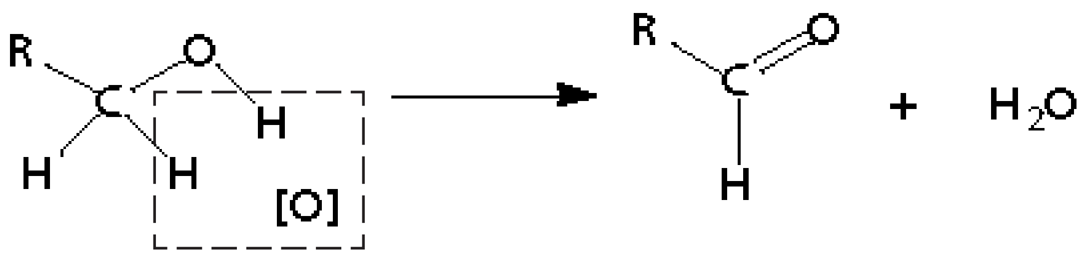
Name of alcohol	***Type of alcohol***	***Colour change observed***
butan-1-ol		
butan-2-ol		
2-methylpropan-2-ol		

Both Prim and Sec alcohols can be oxidised but Tertiary alcohols cannot.

The Oxidation Reaction

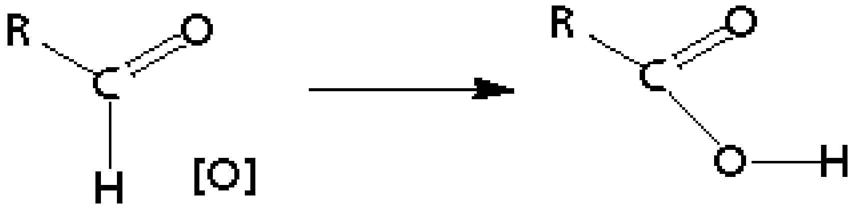
This activity explains the changes which occur when different types of alcohol are oxidised.

Prim *alcohols* can be ***oxi*** in two stages. The *oxidising agent* is simply the source of ***oxy*** [O].



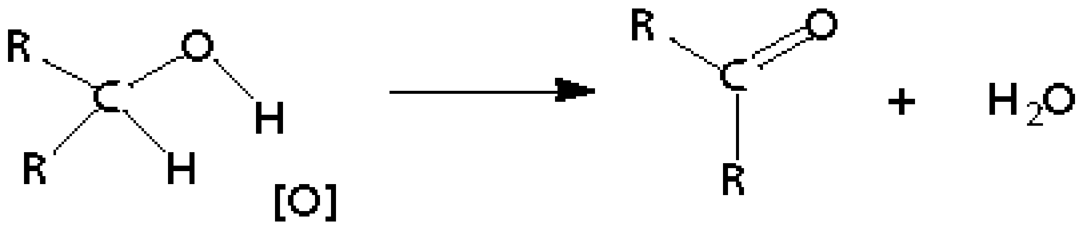
During the first stage the ***hyd*** *group* C—OH is converted into a ***carb*** *group*, C=O. The molecule produced is called an ***ald*** .

The second stage sees the ***ald*** converted into an ***ac*** ***.***



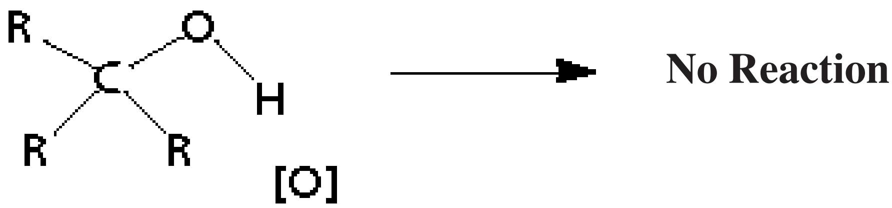
Notice that ***oxi*** can involve the ***loss of hyd*** as well as the ***gain of ox***
(and, of course, oxidation is still the ***loss of elec***)

Sec *alcohols* can also be ***oxi*** , but they can only go through the first stage.
Again,the *oxidising agent* is simply the source of ***oxy*** [O].



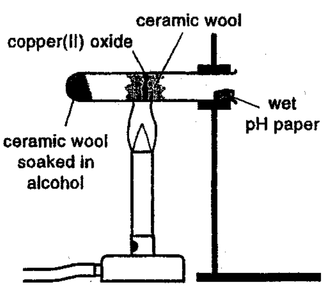
Again, during the first stage of oxidation the ***hyd*** *group* C—OH is converted into a ***carb*** *group*, C=O. The molecule produced this time is called a ***ket*** . The absence of a ***hyd*** atom makes it impossible for this molecule to be ***oxi*** a *second* time to form an ***ac*** .

Ter *alcohols* cannot be ***oxi*** . The absence of ***hyd*** atoms makes *oxidation* impossible.



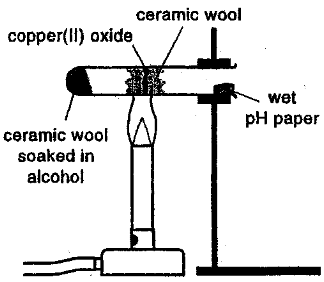
Oxidising With Copper (II) Oxide

This activity investigates another method for oxidising primary and secondary alcohols



When a ***pri*** *alcohol* is passed over heated copper (II) oxide the ***bl*** oxide is converted into ***re*** ***-brown*** copper metal.

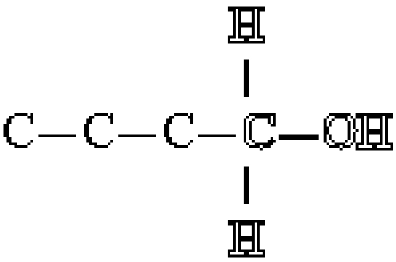
A piece of ***pH paper*** held at the mouth of the test-tube turns ***r*** showing that an ***ac*** has been formed.



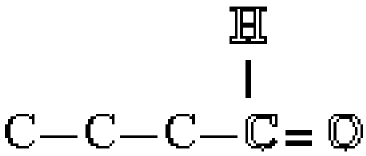
When a ***sec*** *alcohol* is passed over heated copper (II) oxide the ***bl*** oxide is converted into ***re -brown*** copper metal.

A piece of ***pH paper*** held at the mouth of the test-tube stays the same because an ***ac*** has not been formed.

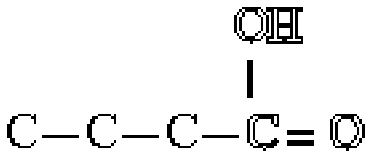
Summary



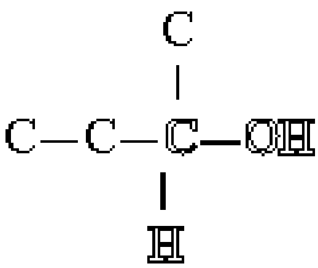
a ***primary*** *alkanol*
(—OH at end of chain)
butan-1-ol



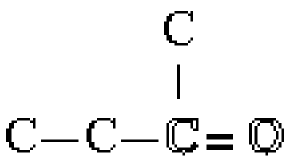
an *alkanal*
(C=O at end of chain)
butanal



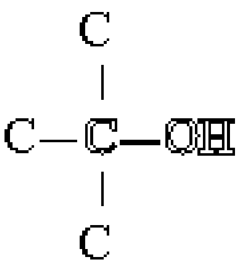
an *alkanoic acid*
(COOH at end of chain)
butanoic acid



a ***secondary*** *alkanol*
(—OH in middle of chain)
butan-2-ol



a *alkanone*
(C=O in middle of chain)
butanone



a ***tertiary*** *alkanol*
(—OH at same place as a branch)
2,methylpropan-2-ol

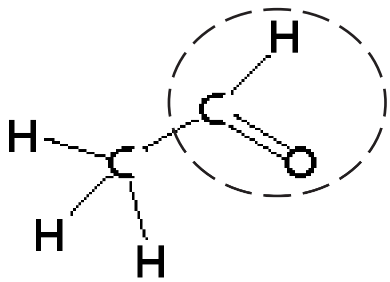
6.6 Aldehydes and Ketones

This lesson looksat the difference between aldehydes and ketones in terms of their molecular structures, systematic names and some distinguishing tests.

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.*

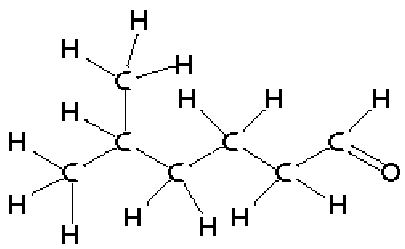


The ***func*** *group* of an aldehyde contains the ***car*** *group* and a ***hyd*** atom - —CHO.

CH_3CHO

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

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

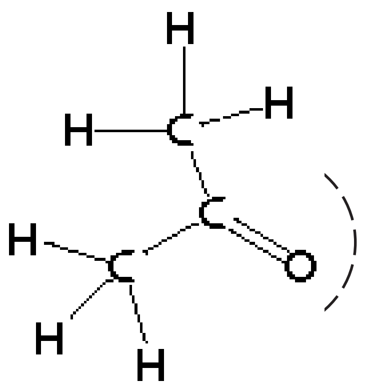
Alkanal Structures	
Name:	2-methylpropanal
Full Structural Formula:	
Shortened Structural Formula:	
Name:	
Full Structural Formula:	
Shortened Structural Formula:	

Name:	
Full Structural Formula:	
Shortened Structural Formula:	CH_3 (branch on third carbon) $CH_3CH_2CHCH_2CH_2CH_2CH_2CHO$

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.*



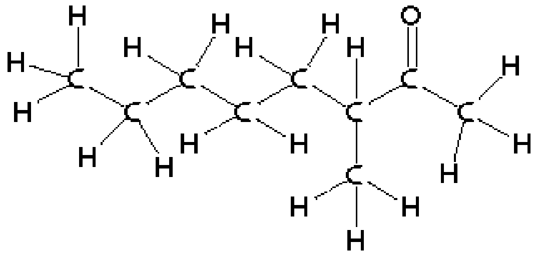
The ***func*** *group* of a ketone is simply the ***car*** *group* by itself.

CH_3COCH_3

The longest carbon chain must include the ***func*** *group*. This molecule is named as ***one***.

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:	

Name:	
Full Structural Formula:	
Shortened Structural Formula:	
Name:	
Full Structural Formula:	
Shortened Structural Formula:	

Distinguishing Tests

PPA

The aim of this experiment is to use mild oxidising agents to distinguish between two carbonyl compounds (X & Y).

*The oxidising agents to be used are **(i)** acidified dichromate solution, **(ii)** Fehling's solution and **(iii)** Tollen's solution.*

*   *State the aim of the experiment*

*   *Why can mild oxidising agents be used to distinguish between aldehydes and ketones?*

Procedure

* *Why were the reaction mixtures* ***not*** *heated directly using a Bunsen burner?*

Results

* *record your observations in tabular form.*

Conclusion

* *State the conclusion of the experiment*

6.7 Methanol and Methanal

This lesson looksat the industrial manufacture of methanol and methanal, two important feedstocks in the chemical industry.

Synthesis Gas

This activity is about the manufacture of synthesis gas, an important feedstock in the chemical industry.

Synthesis gas is a mixture of ***carbon mon*** and ***hyd*** . It can be made from *two sources* by a process called ***ste ref*** .

from coal:

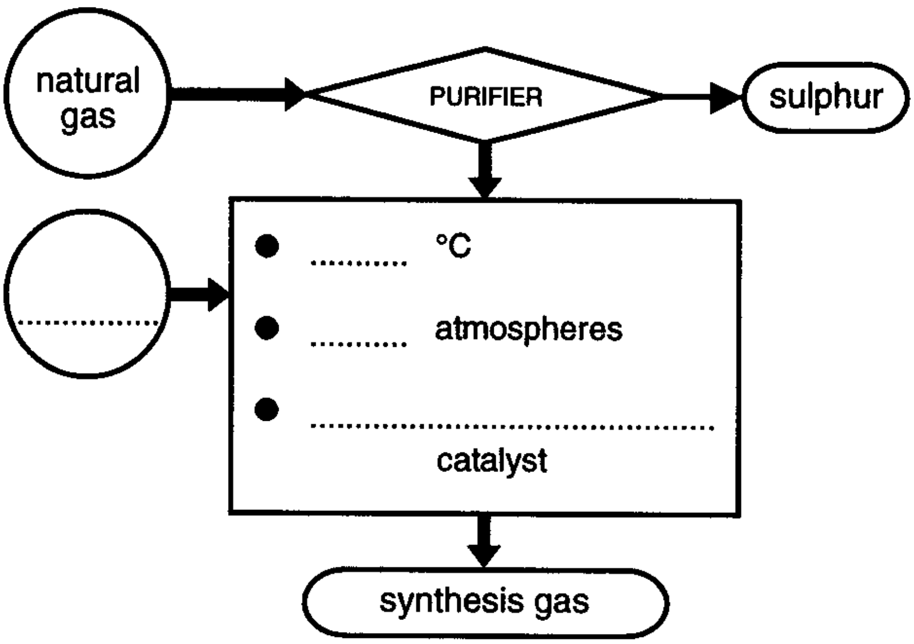
carbon + steam → carbon monoxide + hydrogen

$C_{(s)}$ + → +

from natural gas:

methane + steam → carbon monoxide + hydrogen

$CH_{4(g)}$ + → +



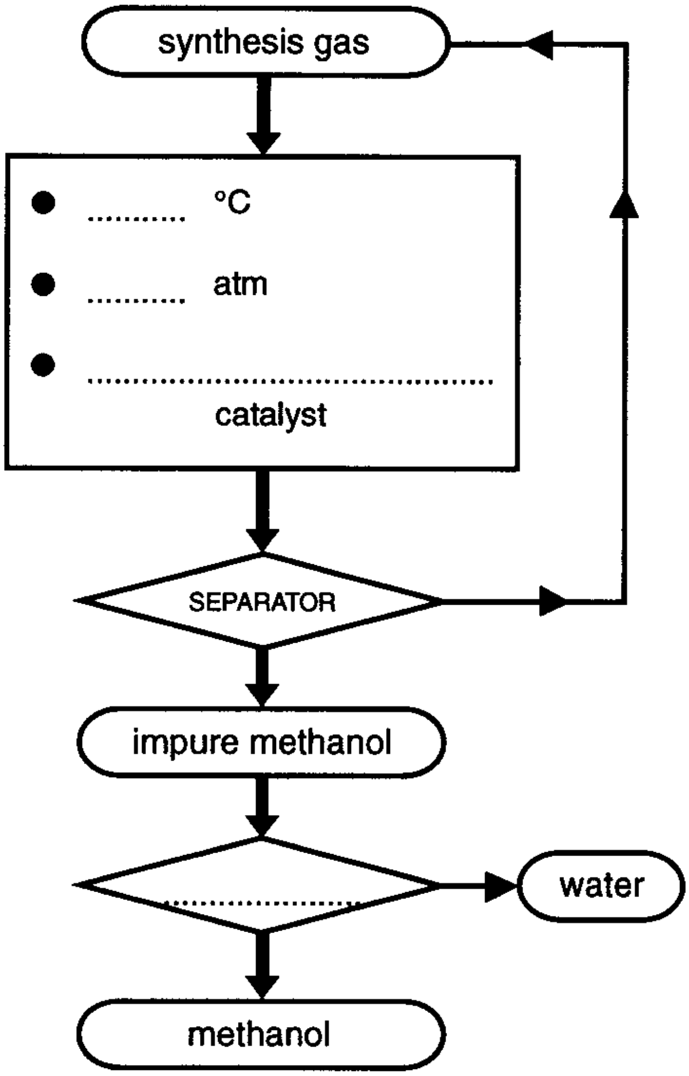
It is important to remove impurities like ***hyd sul*** from ***nat gas*** as they would ***poi*** the ***nic cat*** .

Manufacturing Methanol

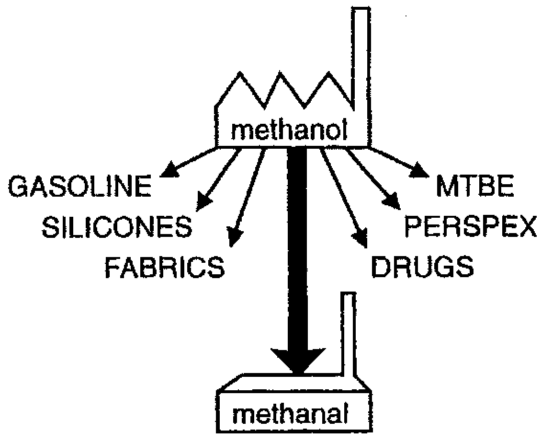
This activity is about the manufacture of methanol from synthesis gas

carbon monoxide + hydrogen → methanol

$CO_{(g)}$ + →



There is rarely 100% conversion of the ***rea*** into ***pro***. Having a ***rec*** *loop* avoids *wasting valuable gases* as well as *avoiding the pollution* and *explosive danger* if the ***unr*** *gases* were simply allowed to escape into the ***atm***



MTBE *(methyltertiarybutylether)* is used as an ***oct*** improver in petrol.

Methanol can also be converted into ***pet*** using *zeolite catalysts*.

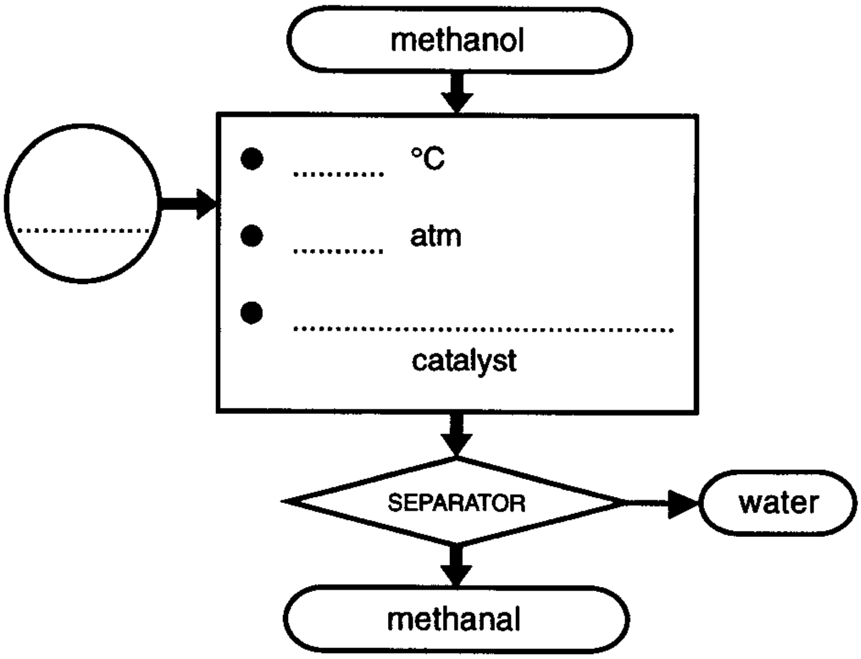
Manufacturing Methanal

This activity is about the manufacture of methanal from methanol.

methanol + oxygen → methanal + water

$CH_3OH_{(l)}$ + →

This reaction can be described as *'catalytic oxidation'* because the *methanol* is **losing hy-*d*** and the reaction requires a ***sil*** ***cat*** .



Methanal, like *methanol*, is a very important ***fee*** in the manufacture of other ***con*** products.

However, the largest use of ***methanal*** is in the manufacture of ***thermo plas*** . (*More in Section 8*)