# Higher Chemistry: Unit 2 – Nature's Chemistry

## Part B – Alcohols, Oxidation and Esters

## Lesson 2 – Oxidation of Alcohols

### Learning Outcomes

By the end of this lesson you should know:

1. What is meant by the terms "oxidation" and "reduction" in carbon chemistry
2. The names of two oxidising agents for alcohols
3. That when some alcohols oxidise, they can produce aldehydes, ketones and carboxylic acids. Some alcohols do not oxidise.
4. How to draw and name carbonyl compounds, aldehydes and ketones.

### Success Criteria

You will have been successful in this lesson if you:

1. Read and learn the notes given
2. Watch the links provided
3. Complete revision questions provided
4. Complete and submit the homework assigned by your class teacher.

There is also a further reading section to help you gain more depth of understanding for this section.

If you have any questions about the content of this lesson, you should ask your class teacher either through your class zoom or via email. The teams will be monitored through the week and someone will get back to you as soon as they can.

### Links to Prior Knowledge

You may wish to revise the following to help you understand this lesson:

- National 5 chemistry – alcohols and carboxylic acids

*You may wish to have a copy of the data booklet handy for this lesson. Download or print a copy of the Higher Chemistry Data Booklet from MS Teams or the SQA website -* https://www.sqa.org.uk/sqa/files_ccc/ChemistryDataBooklet_NewH_AH-Sep2016.pdf

**Notes - Check your class notes - you may have already covered this in class. If so, you do not need to copy this lesson, as it is just a revision of what you covered in school. You may wish to add to your notes with the content below.**

**If you have not covered this in school, then you should either copy, print or save the notes below.**

**A full copy of these notes are available on the Higher Chemistry Teams site and you will receive a paper copy when we return to school.**

# Oxidation of Alcohols

**Click here for a PowerPoint with voice recording from Ms Hastie for this lesson**

## Oxidation and Reduction

In organic (carbon) chemistry oxidation reactions are defined as a reaction which **increases the oxygen to hydrogen ratio** of a molecule. This is achieved by either adding an oxygen atom to a molecule or removing hydrogen atoms.

For example, the reactions below would be described as **oxidation reactions** as the oxygen to hydrogen ratio is increasing.

| | | | | | |
|---|---|---|---|---|---|
| ethanol | $C_2H_5OH$ | → | $C_2H_4O$ ethanal | → | $C_2H_4O_2$ ethanoic acid |
| | O : H | | O : H | | O : H |
| | 1 : 6 | | 1 : 4 | | 2 : 4 (= 1 : 2 ) |

The reverse reaction is called a **reduction reaction**. In organic chemistry, reduction is a **decrease in the oxygen to hydrogen ratio**, by either the adding of hydrogen atoms or the removal of oxygen.

# Oxidising Agents and Products of Oxidation

In an experiment, the following oxidising agents can be used to oxidise primary and secondary alcohols. A colour change occurs when the oxidation takes place:

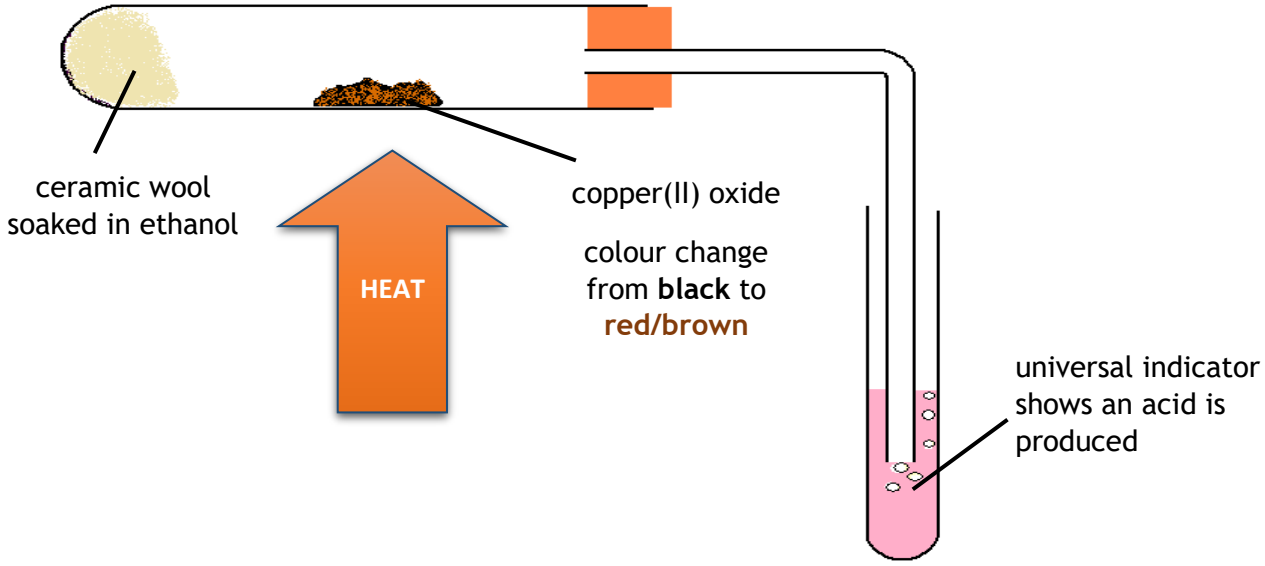
| Oxidising Agent | Colour Change |
|---|---|
| hot copper(II) oxide, CuO | **black** to **red/brown** |
| acidified dichromate, $Cr_2O_7^{2-}$ | **orange** to **green/blue** |

GENERAL RULE:

1. Primary alcohols can be oxidised to aldehydes and further oxidised to carboxylic acids.
2. Secondary alcohols can be oxidised to ketones.
3. Tertiary alcohols cannot be oxidised.

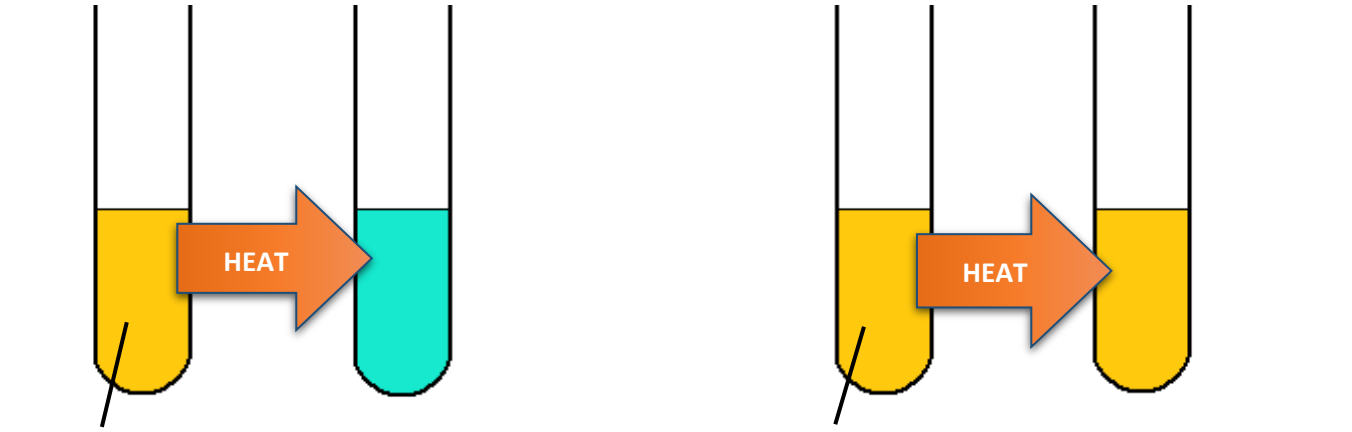
# Using oxidising agents in the laboratory

**1.** Oxidation of ethanol (primary alcohol) using hot copper oxide




*This reaction produces ethanal and ethanoic acid.*

**2.** Oxidation of propan-2-ol (secondary alcohol) and 2-methylpropan-2-ol (tertiary alcohol) using acidified potassium dichromate.



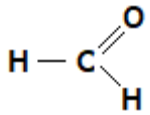
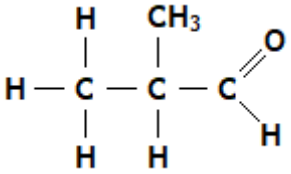
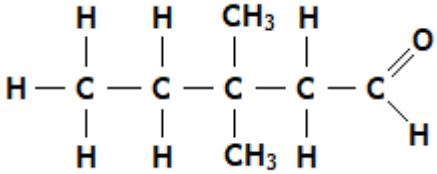

*In this reaction, the secondary alcohol will oxidise to form propanone.*

*The tertiary alcohol will not oxidise.*

# Aldehydes and Ketones (Carbonyl Compounds)

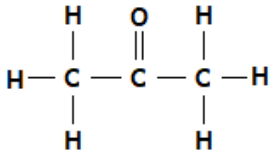
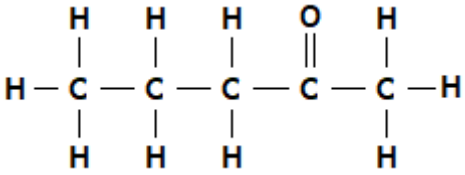
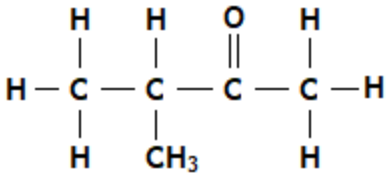
## Aldehydes

**Aldehydes** are a homologous series with the general formula $C_nH_{2n}O$. Aldehydes are identifiable by their carbonyl functional group (-C=O). For aldehydes, the carbonyl group is always positioned on the end of the carbon chain. A selection of aldehydes are shown below:

| Name | Molecular formula | Extended structural formula | Shortened structural formula |
|---|---|---|---|
| methanal | $CH_2O$ |  | $CH_2O$ |
| methylpropanal | $C_4H_8O$ |  | $CH_3CH(CH_3)CHO$ |
| 3,3-dimethylpentanal | $C_7H_{14}O$ |  | $CH_3CH_2C(CH_3)_2CH_2CHO$ |

## Ketones

**Ketones** are a homologous series with the general formula $C_nH_{2n}O$. Ketones are isomers of aldehydes with the same number of carbons and differ only in the position of the carbonyl group (-C=O). In ketones the carbonyl group is positioned somewhere along the middle part of carbon chain, rather than at the end of the chain. A selection of ketones are shown below:

| Name | Molecular formula | Extended structural formula | Shortened structural formula |
|---|---|---|---|
| propanone | $C_3H_6O$ |  | $CH_3COCH_3$ |
| pentan-2-one | $C_5H_{10}O$ |  | $CH_3CH_2CH_2COCH_3$ |
| 3-methylbutanone | $C_5H_{10}O$ |  | $CH_3CH(CH_3)COCH_3$ |

## SUMMARY

1. Oxidation increases the oxygen to hydrogen ratio
2. Oxidising agents for alcohols include:
    - **hot copper(II) oxide** – changes from black to red/brown
    - **acidified dichromate solution** – changes from orange to green
3. **Primary** alcohols can be oxidised to **aldehydes** and then to **carboxylic acids**
4. **Secondary** alcohols can be oxidised to **ketones**
5. **Tertiary** alcohols **cannot be oxidised**.
6. **Aldehydes and Ketones** are two homologous series, both with the general formula **$C_nH_{2n}O$.**
7. **Aldehydes and Ketones** both contain the **carbonyl functional group, -C=O.**

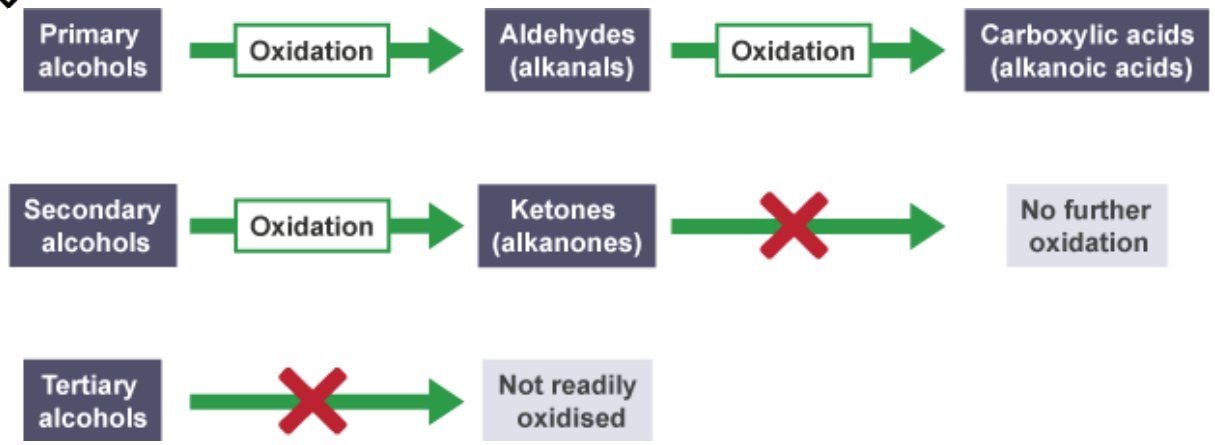



*Image from BBC bitesize*

## Learning Outcomes

You should now know:

1. What is meant by the terms "oxidation" and "reduction" in carbon chemistry
2. The names of two oxidising agents for alcohols
3. That when some alcohols oxidise, they can produce aldehydes, ketones and carboxylic acids. Some alcohols do not oxidise.
4. How to draw and name carbonyl compounds, aldehydes and ketones.

## Further Reading

To learn more about oxidation of alcohols, try the following online resources:

**BBC Bitesize:** https://www.bbc.co.uk/bitesize/guides/zyq22hv/revision/2

**Scholar:** Log in through GLOW

*Higher Chemistry → Nature's chemistry → Oxidation of food → read content 9.1-9.5*

**Evans2 chem web:** https://www.evans2chemweb.co.uk/login/index.php#

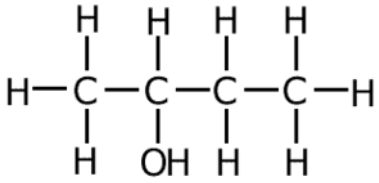
Username: snhs password: giffnock

*Select any teacher → revision material → CfE Higher → Unit 2: Nature's Chemistry → Oxidation of food*

**Check your understanding – Answers the questions below in you class jotter**

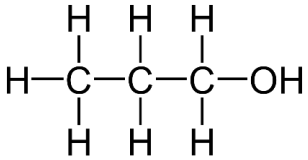
# 2.3 Oxidation of Alcohols (i)

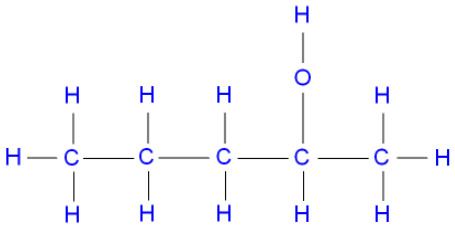
**1.** The structure of Butan-2-ol is shown below:

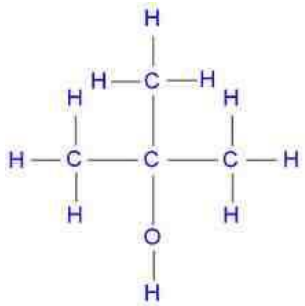


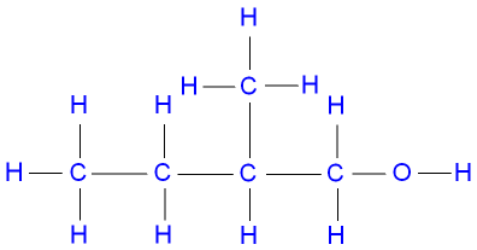
a) Why is butan-2-ol described as a secondary alcohol?
b) Name and draw the full structural formula of the substance that is produced when butan-2-ol is oxidised.
c) Define oxidation, with regards to oxidation of organic compounds.
d) Name two oxidising agents that can be used to oxidise alcohols.

**2.** Name the ketone or aldehyde(and then carboxylic acid) which would be produced if the following can be oxidised:

a) 

b) 

c) 

d) 

e) $CH_3OH$

f) $CH_3CH(OH)CH(CH_3)CH_3$

g) $CH_3CH_2CH_2CH_2C(CH_3)(OH)CH_3$

h) $CH_3C(CH_3)_2CH(OH)CH_3$

# 2.4 Oxidation of Alcohols (ii)

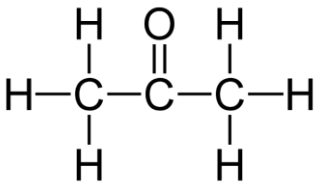
**1.** Give the full structural formula and name for the aldehyde or ketone formed by oxidation of the following alcohols.

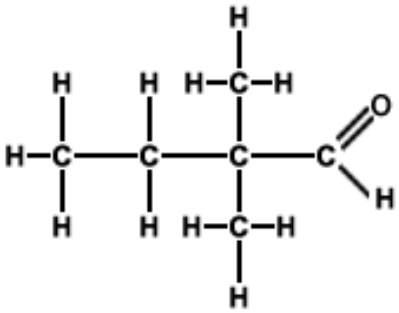
a) ethanol
b) propan-2-ol
c) Hexan-1-ol
d) 4-methyl pentan-1-ol
e) 3,4-dimethyl pentan-2-ol
f) cyclobutanol

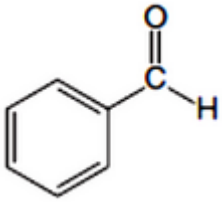
**2.** Alcohol **X**, was oxidised to produce a **neutral** compound **Y,** of molecular mass 58. Compound **Y** could not be oxidised.

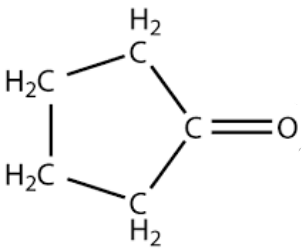
a) Draw the full structural formulae of **X**, and **Y**.
b) Give the name of **X** and Y.
c) What colour change would be observed when X is oxidised using:
i. Hot copper oxide?
ii. Acidified dichromate solution?

**3.** Draw the full structural formula of the **alcohols** that were oxidised to produce the following molecules:

a) 

b) 

c) 

d) 

## EXTENSION WORK

If you have already completed the above exercises in school, you should completed the following blue book questions:

Oxidation of carbon compounds Page 54 Q1-10

**ANSWERS TO Ex 2.3, 2.4 AND EXTENSION WORK WILL BE POSTED ON WEDNESDAY**

## HOMEWORK

You should now complete "Homework 1 – Alcohols & Systematic Carbon Chemistry" in your homework jotter, or the back of your class jotter if you don't have your homework jotter at home with you.

Take a picture of your homework answers and submitted them to your class teacher, through your class team by **1pm on Friday 15th January.**

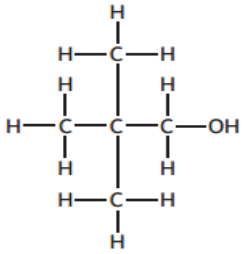
Your teacher will let you know how to submit this and will give you feedback on this homework.

If you have already completed this homework you should send a picture of the extension work above to your teacher.

A copy of the homework is on the next page.

# Homework 1 – Alcohols & Systematic Carbon Chemistry

**1.** What is the systematic name for the compound below?

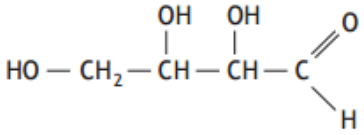


**A** 2,2,2-trimethylethanol
**B** 2,2-dimethylpropan-1-ol
**C** 2,2-dimethylpropan-3-ol
**D** 2,2-dimethylpetan-1-ol

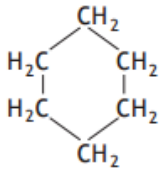
**2.** What type of alcohol is the molecule in Question 1?

**A** primary
**B** secondary
**C** tertiary
**D** unsaturated

**3.** Which of the following compounds will be the best solvent for the molecule below



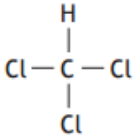
**A**



**B** $CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$

**C** $CH_3-CH_2-OH$

**D**



**4.** Which of the following is an isomer of 2,2-dimethylpentan-1-ol

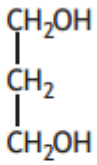
**A** $CH_3CH_2CH(CH_3)CH_2OH$
**B** $(CH_3)_3CCH(CH_3)CH_2OH$
**C** $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH$
**D** $(CH_3)_2CHC(CH_3)_2CH_2CH_2OH$

**5.** Which of the following is secondary alcohol

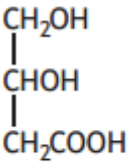
**A** $CH_3CH_2CH(OH)CH_3$
**B** $(CH_3)_3CC(CH_3)(OH)CH_3$
**C** $CH_3CH_2CH_2CH_2CH_2CH_2OH$
**D** $(CH_3)_2CHC(OH)_2CH_2CH_3$

Questions **6** and **7** refer to the structures below

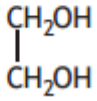
**A**



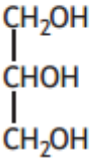
**C**



**B**



**D**



**6.** Which of the compounds is a triol?

**7.** Which molecule is propan1,3-diol?

**8.** Which of the following is responsible for the solubility of alcohols in water?

**A** London Dispersion Forces
**B** Permanent dipole to dipole interactions
**C** Hydrogen bonding
**D** Covalent bonding

**9.** For each of the following compounds:

(i) Draw the full structural formula
(ii) Write the shortened structural formula
(iii) State whether it is a primary, secondary or tertiary alcohol

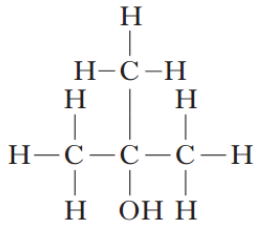
(a) 2-methylpentan-1-ol (2)

(b) 2,3-dimethylbutan-2-ol (2)

(c) 3,4-dimethylhexan-2-ol (2)

**10.** Name the following compounds

(a)



(1)

(b) $CH_3CH(CH_3)C(CH_3)(OH)CH_2CH_3$ (1)

**11.** The table below compares properties of butane and propan-1-ol.
These molecules can be compared because they have similar molecular masses.

| Property | butane | propan-1-ol |
|---|---|---|
| Mass of one mole | 58g | 60g |
| Boiling Point / °C | -1 | 97 |
| Solubility in water | insoluble | soluble |

(a) Name the functional group present in propan-1-ol (1)

(b) Which molecule would you expect to have a higher viscosity (1)

(c) **Explain clearly** why propan-1-ol has a much higher boiling point than butane.
You should mention the type of intermolecular force involved and how it arises. (2)

**Total = 20**