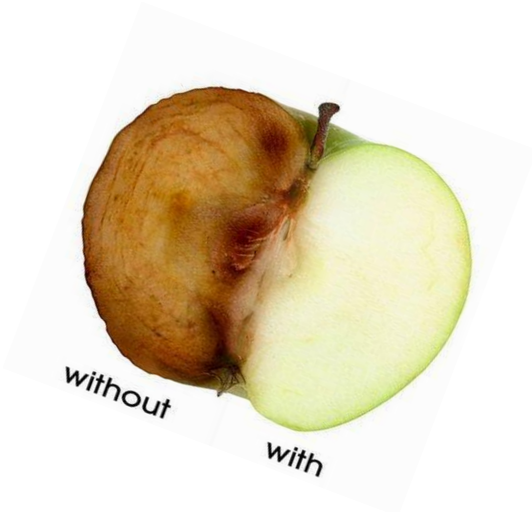
Cathkin High School
CfE Higher Chemistry

Nature's Chemistry
Oxidation of Food



No.	Learning Outcome	Understanding?
1	Branched-chain alcohols with no more than 8 carbon atoms in the longest chain can be named from structural formulae.	☺ 😐 ☹
2	Given the names of branched-chain alcohols, structural formulae can be drawn and molecular formulae written.	☺ 😐 ☹
3	Alcohols can be classified as primary, secondary or tertiary.	☺ 😐 ☹
4	Primary alcohols are oxidised, first to aldehydes and then to carboxylic acids.	☺ 😐 ☹
5	Secondary alcohols are oxidised to ketones.	☺ 😐 ☹
6	When applied to carbon compounds, oxidation results in an increase in the oxygen to hydrogen ratio.	☺ 😐 ☹
7	Hot copper (II) oxide or acidified dichromate (VI) solutions can be used to oxidise primary and secondary alcohols.	☺ 😐 ☹
8	Tertiary alcohols cannot be oxidised.	☺ 😐 ☹

9	Branched-chain carboxylic acids, with no more than 8 carbon atoms in the longest chain, can be named from structural formulae.	☺ 😐 ☹
10	Given the names of branched-chain carboxylic acids, structural formulae can be drawn and molecular formulae can be written.	☺ 😐 ☹
11	Oxygen reacts with edible oils giving the food a rancid flavour.	☺ 😐 ☹
12	Antioxidants are molecules which will prevent these oxidation reactions taking place.	☺ 😐 ☹
13	Ion-electron equations can be written for the oxidation of many antioxidants.	☺ 😐 ☹

Alcohols

Alcohols make up a group of organic compounds which contain the -OH group, called the hydroxyl group. The -OH (or -O-H) group is known as a functional group as this gives the molecules its specific properties. The hydroxyl group is attached to carbon together with atoms of hydrogen.

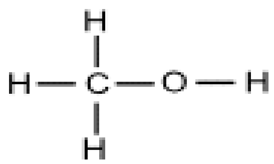
The presence of the hydroxyl group in these compounds is indicated by the '-ol' ending of the name of the alcohol.

Alcohol	Molecular Formula	Shortened Structure
Methanol	CH_3OH	CH_3OH
Ethanol	C_2H_5OH	CH_3CH_2OH
Propanol	C_3H_7OH	$CH_3CH_2CH_2OH$
Butanol	C_4H_9OH	$CH_3CH_2CH_2CH_2OH$ or $CH_3(CH_2)_3OH$
Pentanol	$C_5H_{11}OH$	$CH_3(CH_2)_4OH$
Hexanol	$C_6H_{13}OH$	$CH_3(CH_2)_5OH$
Heptanol	$C_7H_{15}OH$	$CH_3(CH_2)_6OH$
Octanol	$C_8H_{17}OH$	$CH_3(CH_2)_7OH$

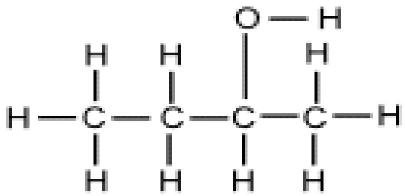
As the alcohols are based on a family of hydrocarbons called alkanes, these alcohols can also be called alkanols. The alkanols are a homologous series with the general formula $C_nH_{2n+1}OH$

Isomers exist for alkanols, and the presence of the -OH or hydroxyl group increases the possibility of isomers because the position of the hydroxyl group can vary. **You will be expected to name and draw straight chain and branched chain isomers up to C_8.**

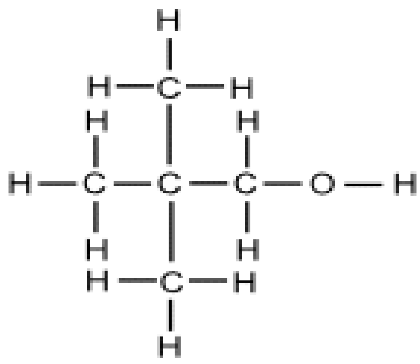
When naming alkanols, the longest chain containing the hydroxyl group is named first and numbered so that the hydroxyl group in attached to the lowest numbered carbon atom.



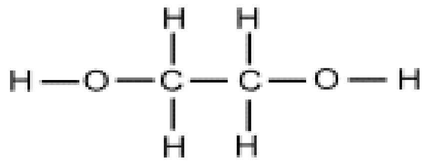
methanol



butan-2-ol



2,2-dimethylpropan-1-ol



ethan-1,2-diol

The shortened structural formula for 2,2-dimethylpropan-1-ol is $CH_3C(CH_3)_2CH_2OH$

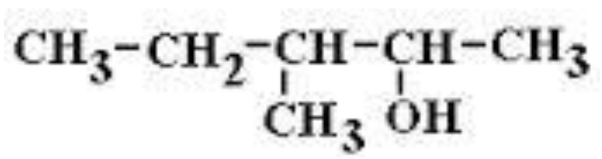
<u>How to name an alcohol from the structural formula:</u>

1. Look for the longest continuous chain of carbon atoms on which the -OH group it attached and name this as the parent compound.
2. The parent name is placed at the end of the name of the compound.
3. Look for groups which form branches on the chain and identify them.
4. Different groups are written in alphabetical order before the parent name e.g. 'ethyl' before 'methyl'.
5. If there are 2 identical groups the prefix 'di' is placed before the name of the branch e.g. 'dimethyl', 'diethyl' etc
6. The prefixes 'tri' and 'tetra' are used if there are 3 or 4 repetitions respectively of the same group on the parent chain.

7. To specify the position of each group, the parent chain is numbered from the end which results in the lowest possible numbers in the formula.

Drawing structural formula using the alcohol name:

If you were asked to draw the full structural formula of 3-methylpentan-2-ol, you would recognise it was an alcohol (alkanol) from the '-ol' end, that it has 5 carbon atoms in its chain (from the 'pentan' part of the name) and that it has a methyl branch on the 3rd carbon (from the 3-methy start of the name).
Draw a line of 5 carbon atoms with bonds between each C atom. Put the other bonds to each carbon atom (4 in total on each C atom). Count from the end of the chain to find the 2nd carbon atom. To one of the bonds on this atom, attach an -OH group (or an -O-H group to show all of the bonds needed in a full structure. Count from the same end of the chain to find the 3rd carbon atom. To one of the bonds on the atom, attach a -CH_3 group (the methyl branch). Finally put H atoms on the ends of all of the other bonds not connected to carbon atoms.



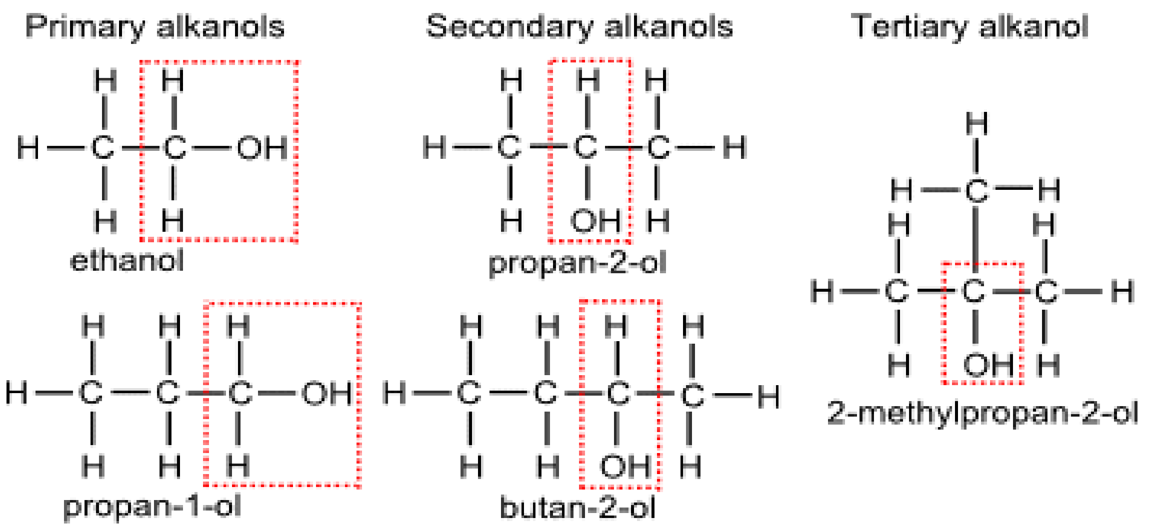
Classification of Alcohols

Alcohols can be classified in 3 groups.

1. ***Primary Alcohols (1°)*** – the carbon atom to which the hydroxyl group is attached to is bonded to no more than one other carbon. The other bonds are to hydrogen atoms.

2. ***Secondary Alcohols (2°)*** – the carbon atom to which the hydroxyl group is attached to is bonded to two other carbon atoms. Only one bond is to a hydrogen atom.

3. ***Tertiary Alcohols (3°)*** – the carbon atom to which the hydroxyl group is attached to is bonded to three other carbon atoms. There are no bonds to hydrogen atoms.



Oxidation of Alcohols

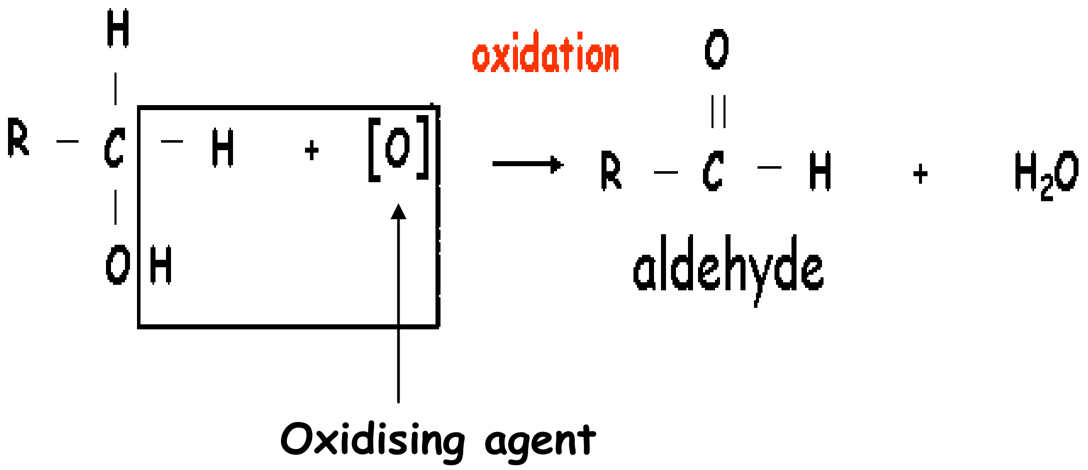
The *oxidation* of an organic compound causes the oxygen to hydrogen ratio within the molecule to increase. This can be achieved by either adding oxygen to or removing hydrogen from the molecule.

In the *reduction* of an organic compound the oxygen to hydrogen ratio is decreased by removing oxygen or adding hydrogen.

Complete oxidation of an organic compound is also known as combustion. When an alcohol is combusted carbon dioxide and water are produced. Some organic compounds like alcohols can be partially oxidised to produce different organic compounds.

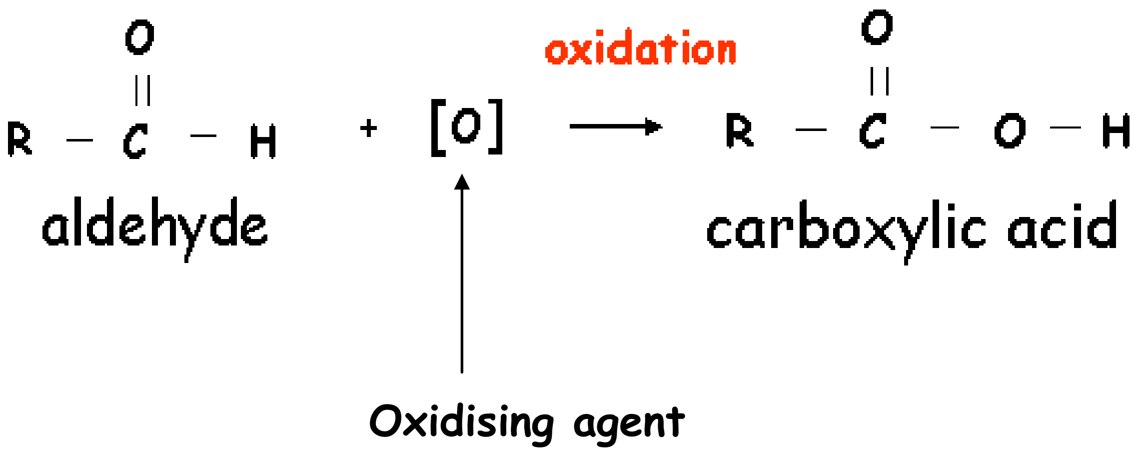
<u>Primary Alcohols</u> can be oxidised in two stages. The first stage changes the alcohol to an aldehyde.

Primary Alcohol → Aldehyde + water



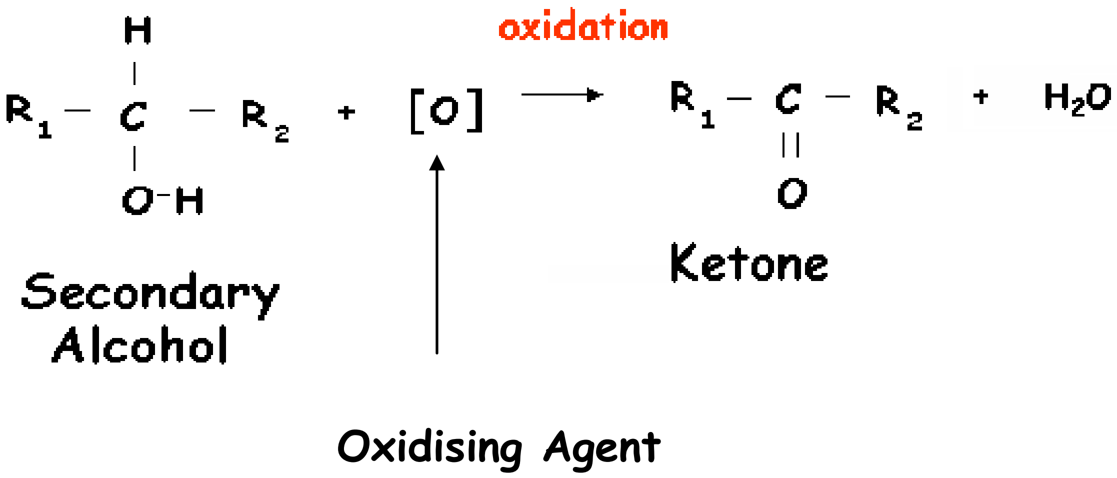
In the second stage of oxidation, the aldehyde is further oxidised to produce a carboxylic acid.

Aldehyde → Carboxylic acid



<u>Secondary Alcohols</u> can be oxidised in one stage to produce ketones.

Secondary Alcohol → Ketone + water



<u>Tertiary Alcohols</u> cannot be oxidised readily.

In order to oxidise a primary or secondary alcohol an appropriate ***oxidising agent*** should be used. Commonly used oxidising agents are listed below.

- Acidified potassium dichromate solution
- Acidified potassium permanganate solution
- Heated solid copper (II) oxide

Carboxylic acids

Carboxylic acids contain the carboxyl functional group, -COOH and can be recognised from their name by the '-oic' ending in the name.
If this group is also attached to an alkane chain, the carboxylic acid is called an alkanoic acid.

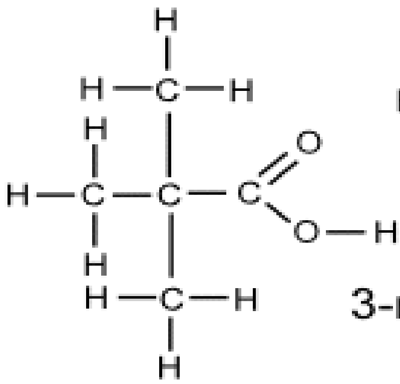
Alkanoic acids, $C_nH_{2n+1}COOH$

One exception to this general formula is methanoic acid, HCOOH.

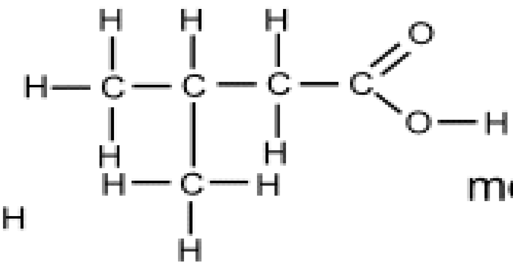
Alkanoic acid	**Molecular Formula**	**Shortened Structure**
Methanoic acid	HCOOH	HCOOH
Ethanoic acid	CH_3COOH	CH_3COOH
Propanoic acid	C_2H_5COOH	CH_3CH_2COOH
Butanoic acid	C_3H_7COOH	$CH_3CH_2CH_2COOH$ or $CH_3(CH_2)_2COOH$
Pentanoic acid	C_4H_9COOH	$CH_3(CH_2)_3COOH$
Hexanoic acid	$C_5H_{11}COOH$	$CH_3(CH_2)_4COOH$
Heptanoic acid	$C_6H_{13}COOH$	$CH_3(CH_2)_5COOH$
Octanoic acid	$C_7H_{15}COOH$	$CH_3(CH_2)_6COOH$

You will be expected to name straight-chain and branched-chain carboxylic acids, with up to eight carbon atoms in their longest chain given their structural formulae.
You will also be expected to draw structural and write molecular formulae when you are given the names of straight-chain or branched-chain carboxylic acids

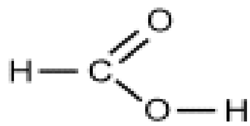
Some examples of full structures and names are shown below



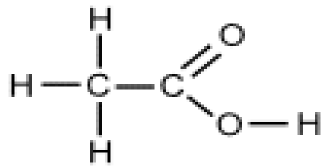
2,2-dimethyl propanoic acid



3-methylbutanoic acid



methanoic acid



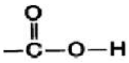
ethanoic acid

<u>How to name a carboxylic from the structural formula:</u>

1. Look for the longest continuous chain of carbon atoms on which the -COOH group it attached and name this as the parent compound. The carbon atom in the carboxyl group is included in the parent name of the compound e.g. a two-carbon chain attached to a carboxylic acid group would give the parent compound the name 'propanoic acid'
2. The parent name is placed at the end of the name of the compound.
3. Look for groups which form branches on the chain and identify them.
4. Different groups are written in alphabetical order before the parent name e.g. 'ethyl' before 'methyl'.

5. If there are 2 identical groups the prefix 'di' is placed before the name of the branch e.g. 'dimethyl', 'diethyl' etc
6. The prefixes 'tri' and 'tetra' are used if there are 3 or 4 repetitions respectively of the same group on the parent chain.
7. To specify the position of each group, the parent chain is numbered such that the carbon atom in the carboxyl group is C1.

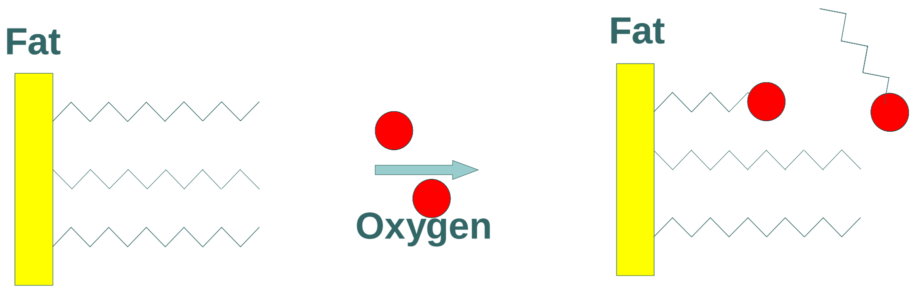
<u>Drawing structural formula using the carboxylic acid name:</u>

If you were asked to draw the full structural formula of 2-methylbutanoic acid, you would recognise it was an carboxylic acid (alkanoic acid) from the '-oic' end, that it has 4carbon atoms in its chain (from the 'butan' part of the name) and that it has a methyl branch on the 2rd carbon (from the 2-methy start of the name).
Draw a line of 4 carbon atoms with bonds between each C atom. Put the other bonds to each carbon atom (4 in total on each C atom). To one of the bonds on an end carbon atom, attach an -OOH group (or  group to show all of the bonds needed in a full structure. Count from the same end of the chain to find the 2rd carbon atom. To one of the bonds on the atom, attach a -CH_3 group (the methyl branch). Finally put H atoms on the ends of all of the other bonds not connected to carbon atoms.

Oxidation of Foods

Oxidation of food can occur when food is exposed to oxygen in the air. Foods which contain fats and oils are at a particularly high risk of oxidation.

Oxidation reactions involving oxygen molecules from the air damage the structure of the fat or oil causing degradation of long fatty-acid chains and formation of short-chain oxidation products. **The oxidation of unsaturated oils and fats** primarily takes place via a *free-radical*-mediated process and **can lead to *rancidity*** (*rancidus* [Latin] = stinking), which negatively affects both odour and taste, and has an impact on safety for human consumption.



Reducing the rate of oxidation of foodstuffs

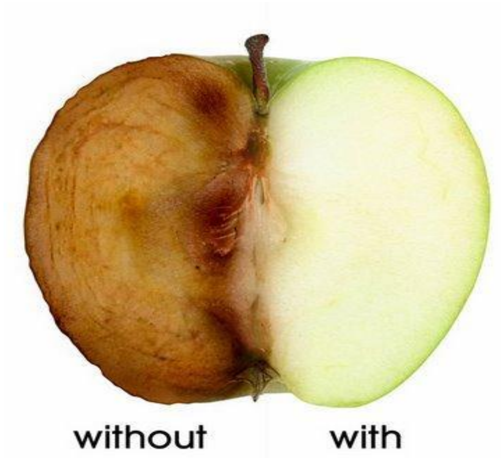
The rate of oxidation of foodstuffs can be slowed down by reducing the temperature by refrigeration. Packaging under a vacuum or under an inert gas such as nitrogen can also reduce the oxidation rate by reducing the concentration of oxygen (air). Crisp manufacturers fry potatoes under a blanket of steam to reduce the oxygen concentration, thus extending the lifetime of both the frying oil and of the crisps.

Although all of these methods of reducing oxidation are fairly effective, it is still usual to add antioxidant(s) to foodstuffs to prolong their shelf-life.

Antioxidants **are molecules that reduce the rate of oxidation reactions** involving the transfer of electron(s) to an oxidising agent. Antioxidants are often added to foodstuffs to minimise oxidative damage.

An effective classroom demonstration to illustrate the benefits of antioxidants in foodstuffs involves cutting an apple in half and leaving one side exposed to the oxygen in the air. The other side is coated in lemon juice, which contains a high concentration of the antioxidant vitamin C. After a few hours, the untreated half becomes brown due to free-radical-induced oxidative damage, whereas the treated half remains undamaged due to the antioxidant properties of the vitamin C.

Oxidation occurs when the apple is left exposed to air



The apple is protected when dipped in orange juice containing the antioxidant vitamin C

How Antioxidants Work

When edible fats and oils are oxidised free radicals are produced. A free radical is a highly reactive species which contains an unpaired electron. Free radicals can damage food by removing electrons. Antioxidants work by "mopping-up" free radicals and so protecting the food. This happens when antioxidant molecules donate an electron to the free radical. This forms a stable pair of electrons, stabilizing the free radical. During this process the antioxidant molecule become oxidised as it loses an electron. **Ion-electron equations can be used to show how antioxidant molecules are oxidised.**

$C_6H_8O_6 \longrightarrow C_6H_6O_6 + 2H^+ + 2e^-$

Vitamin C DHA

(ascorbic acid) (dehydroascorbic acid)

Sources of Antioxidants

Antioxidants can be natural or synthetic. Natural antioxidants tend to be short-lived and therefore synthetic antioxidants are used when a longer shelf-life is preferred. In reality, several antioxidants are often added in combination to foodstuffs to give the most effective action.

Vitamin C and its salts are added to soft drinks, jams, condensed milk and sausage to prevent oxidation. The tocopherols are members of the vitamin E family and are found mainly in nuts, sunflower seeds, soya and maize shoots. They are mostly used for preserving vegetable oils, margarine and cocoa products.

Antioxidant	Natural/synthetic	E number	Types of food
Vitamin C (ascorbic acid)	Natural	E300	Fruits, jams, vegetables
Vitamin E (tocopherols)	Natural	E306	Oils, meat pies, soya beans
Butylated hydroxyanisole (BHA)	Synthetic	E320	Margarine, cheese, crisps

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Oxidation of Food - Glossary

Word	Meaning
Alcohols	Organic compounds containing the hydroxyl (-OH) group.
Primary (1°) Alcohols	Alcohols in which the hydroxyl is bonded to carbon which is bonded to no more than one other carbon.
Secondary (2°) Alcohols	Alcohols in which the hydroxyl is bonded to a carbon which is bonded to two other carbons.
Tertiary (3°) Alcohols	Alcohols in which the hydroxyl is bonded to a carbon which is bonded to three other carbons.
Oxidation	A reaction in which an organic compounds has the oxygen to hydrogen ratio increased. Oxygen can be added or hydrogen can be removed.
Reduction	A reaction in which an organic compound has the oxygen to hydrogen ratio reduced. Oxygen can be removed or hydrogen can be added.
Carboxylic Acids	Organic compounds containing the carboxyl (-COOH) group.
Rancidity	Deterioration of flavour and odour.
Free Radical	Extremely reactive molecules with an unpaired electron.
Antioxidants	Molecules which donate an electron to free-radicals, preventing the deterioration of food.
Oxidising Agent	A substance which causes oxidation of another substance and so undergoes reduction.