

























Cathkin High School CfE Higher Chemistry



Nature's Chemistry Chemistry of Cooking



No.	Learning Outcome	Understanding?
1	Many flavour and aroma molecules are aldehydes.	  
2	Aldehydes and ketones both contain the carbonyl functional group.	  
3	Aldehydes and ketones can be recognised from the "-al" and "-one" name endings respectively.	  
4	Straight-chain and branched-chain aldehydes and ketones with no more than 8 carbon atoms in their longest chain can be named from structural formulae.	  
5	Given the names of straight-chain or branched-chain aldehydes and ketones, structural formulae can be drawn and molecular formulae written.	  
6	Aldehydes, but not ketones can be oxidised to carboxylic acids.	  
7	Copper (II) oxide, Fehling's solution, Tollen's reagent and acidified dichromate solution can be used to differentiate between an aldehyde and a ketone.	  

8	Within proteins, the long-chain molecules may be twisted to form spirals, folded into sheets, or wound around to form other complex shapes. For more info see Proteins Key Area.	
9	The chains are held in these forms by intermolecular bonding between the side chains of the constituent amino acids.	
10	When proteins are heated, during cooking, these intermolecular bonds are broken allowing the proteins to change shape (denature). These changes alter the texture of foods.	

Flavours in Food

Many of the flavours in foods are due to the presence of volatile molecules. Normally these molecules are trapped in the cell. However, during cooking the cell walls can be broken by moisture within the cell evaporating and rupturing the walls. Also chemicals can damage the walls which are made of a structural carbohydrate called cellulose.

Volatile flavour molecules can then leave the food and enter the air. Also some may dissolve in the cooking liquid and be lost. So the method and time of cooking is important in preserving flavours. Flavour molecules can be water-soluble or oil/fat-soluble. You can preserve the flavour by using water for cooking foods that contain oil/fat-soluble flavours such as green beans and broccoli, and using oil/fat to cook foods that are richer in water-soluble flavours such as asparagus. Overcooking food using either method will cause more flavour to be lost.



There are at least five basic taste qualities: sweet, sour, bitter, salty, and umami. (Umami, or savoury, is the taste that comes from glutamate, found in chicken broth, meat extracts, and some cheeses.) Our nose can detect more than 10000 different smells. If there is hydrogen bonding between the molecules responsible for smell, this will reduce the volatility of the molecule.

Many flavour and aroma molecules belong to the family called aldehydes e.g. in alcoholic drinks such as whisky where much of the flavour is developed as oxygen diffuses into the cask forming aldehydes from the alcohol. The toxicity of aldehydes, however, can result in unfortunate symptoms such as severe headaches.

Aldehydes and Ketones

Aldehydes and ketones both contain the carbonyl functional group, $>C=O$.

Aldehydes based on the alkane hydrocarbons are called alkanals and the -al ending identifies the substance as an aldehyde. They have the functional group -CHO.

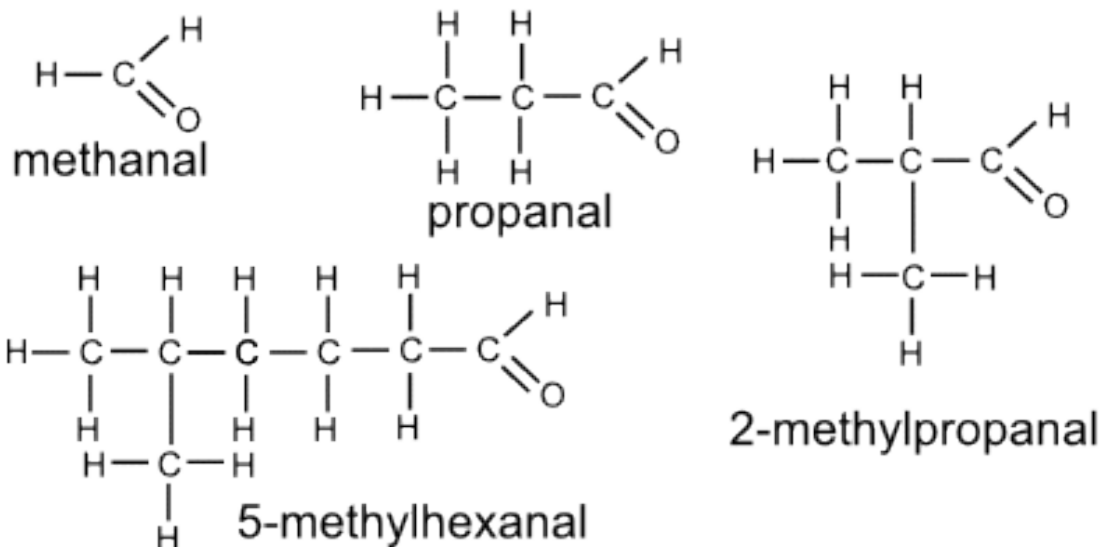
Ketones which are based on the alkane hydrocarbons are called alkanones and the -one ending identifies the substance as a ketone. Ketones all have the $>C=O$ group.

The functional group of alkanals, -CHO always occupies the number 1 carbon atom of the chain.

Alkanal	Molecular Formula	Shortened Structure
Methanal	HCHO	H-CHO
Ethanal	CH ₃ CHO	CH ₃ -CHO
Propanal	C ₂ H ₅ CHO	CH ₃ CH ₂ CHO
Butanal	C ₃ H ₇ CHO	CH ₃ CH ₂ CH ₂ CHO or CH ₃ (CH ₂) ₂ CHO
Pentanal	C ₄ H ₉ CHO	CH ₃ (CH ₂) ₃ CHO
Hexanal	C ₅ H ₁₁ CHO	CH ₃ (CH ₂) ₄ CHO
Heptanal	C ₆ H ₁₃ CHO	CH ₃ (CH ₂) ₅ CHO
Octanal	C ₇ H ₁₅ CHO	CH ₃ (CH ₂) ₆ CHO

Isomers exist for alkanals by branching of the hydrocarbon chain, but the -CHO group is always at the end of the chain.

When naming alkanals, the longest chain containing the -CHO functional group is named first and numbered so that the carbon atom in the -CHO group is number 1.



The shortened formula for 5-methylhexanal is $\text{CH}_3\text{CH}(\text{CH}_3)(\text{CH}_2)_3\text{CHO}$

You will be expected to name straight-chain and branched-chain aldehydes, with no more than eight carbon atoms in their longest chain from structural formulae. You will also be expected to draw structural formulae and write molecular formulae given the names of straight-chain or branched-chain aldehydes.

Ketones are a homologous series with the general formula $\text{C}_n\text{H}_{2n+1}\text{COC}_n\text{H}_{2n+1}$.

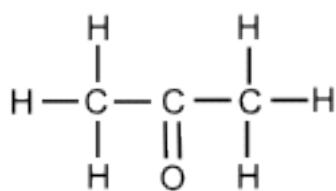
The functional group of ketones, $>\text{C}=\text{O}$ is never at the end of the chain.

The chain is numbered from the end that gives the lowest number to the carbon atom of the carbonyl group.

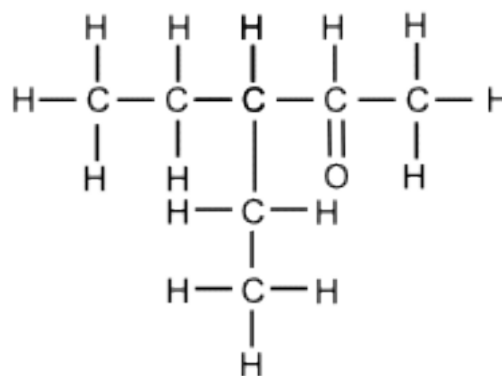
The smallest alkanone contains 3 carbon atoms and is called propanone.

Alkanone	Molecular Formula	Shortened Structure
Propanone	$\text{CH}_3\text{-CO-CH}_3$	CH_3COCH_3
Butanone	$\text{C}_2\text{H}_5\text{-CO-CH}_3$	$\text{CH}_3\text{CH}_2\text{-COCH}_3$
Pentan-2-one	$\text{C}_3\text{H}_7\text{-CO-CH}_3$	$\text{CH}_3(\text{CH}_2)_2\text{COCH}_3$
Hexan-2-one	$\text{C}_4\text{H}_9\text{-CO-CH}_3$	$\text{CH}_3(\text{CH}_2)_3\text{COCH}_3$
Heptan-2-one	$\text{C}_5\text{H}_{11}\text{-CO-CH}_3$	$\text{CH}_3(\text{CH}_2)_4\text{COCH}_3$
Octan-2-one	$\text{C}_6\text{H}_{13}\text{-CO-CH}_3$	$\text{CH}_3(\text{CH}_2)_5\text{COCH}_3$

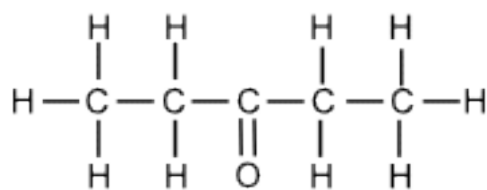
You will be expected to name straight-chain and branched-chain ketones, with no more than eight carbon atoms in their longest chain from structural formulae. You will also be expected to draw structural formulae and write molecular formulae given the names of straight-chain or branched-chain ketones.



propanone



3-ethylpentan-2-one



pentan-3-one

Oxidation of Aldehydes and Ketones

Oxidising agents such as copper (II) oxide, Fehling's (or Benedict's) solution, acidified potassium dichromate or Tollen's reagents will convert aldehydes to carboxylic acids.

The product of the oxidation of ethanal is an alkanoic acid called ethanoic acid.

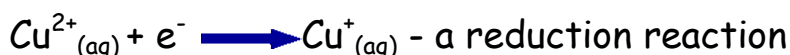
The reaction is classed as an oxidation because of an increase in the oxidation:hydrogen ratio.

Ethanal, CH_3CHO has an oxygen:hydrogen ratio of 1:4 whereas the product ethanoic acid, CH_3COOH has an ratio of O:H of 2:4 or 1:2. So this is an increase in the O:H ratio and is known as oxidation.

If copper(II) oxide is used as the oxidising agent, the black colour of the copper(II) oxide changes to red-brown copper.

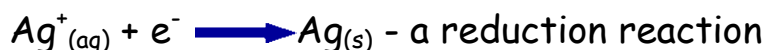


If Fehling's (or Benedict's) solution is used as the oxidising agent, the blue colour of Cu^{2+} changes to the brown coloured Cu^+ ion.



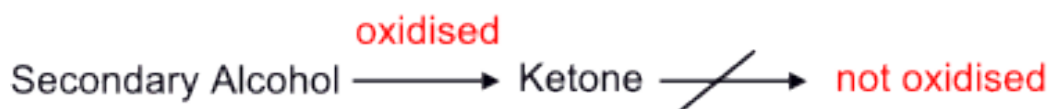
If acidified potassium dichromate solution is used as the oxidising agent, the orange colour of $\text{Cr}_2\text{O}_7^{2-}$ changes to the green/blue Cr^{3+} ions.

If Tollen's reagent is used, the colourless silver(I) ion dissolved in ammonia is converted to silver and a silver mirror is produced inside the glassware.



Ketones do not undergo oxidation and this fact can be used to distinguish aldehydes from ketones.

Reagent	Aldehyde	Ketone
Copper(II) oxide	Black to Red-Brown	No change
Acidified Potassium Dichromate	Orange to Green/Blue	No change
Fehling's (or Benedict's) solution	Blue to Red-Brown	No change
Tollen's reagent	Colourless to Silver	No change



Cooking Proteins

Proteins are complex molecules made from long, amino acid chains which are also branched. **The chains are held together by intermolecular bonding between the side chains of the constituent amino acids.** Hydrogen bonds occur between the amide links and between other groups present in the molecule. **Proteins form three-dimensional structures which are sheets, spirals or coils.**

When proteins are heated, during cooking, these intermolecular bonds are broken allowing the proteins to change shape (*denature*). These changes alter the texture of foods.



For example, egg whites contain many molecules of a globular protein called albumen. When an egg is boiled or fried, the protein structure is irreversibly changed and a solid is made. During cooking, the protein is denatured and the protein chains unwind and, as they can now form intermolecular bonds with neighbouring albumen molecules, a network of interconnected proteins forms causing the egg white to solidify.



The structure of meat changes when cooked. Different temperatures are required for cooking meats with different levels of connective tissue. Joints containing a lot of connective tissue become tender if cooked at over 60°C as the collagen forming the tough connective tissue, denatures. The tender lean meat found in cuts such as fillet steaks have less connective tissue and should not be cooked at too high a temperature, because in this case the protein molecules start to bunch together resulting in the meat becoming tougher.

Chemistry of Cooking - Glossary

Word	Meaning
Volatile	Volatile Organic Compounds (VOCs) are chemicals that will evaporate easily into the air usually at room temperature and often give a distinctive smell.
Cellulose	A structural carbohydrate found in the cell walls of plants and made from many glucose molecules joined together.
Aldehyde	A compound which contains the $-CHO$ group. Some aldehydes are called alkanals.
Ketone	A compound which contains the $>CO$ group. Some ketones are called alkanones.
Denature	A permanent chemical change to the physical shape of a protein/enzyme. This can happen at high temperatures.