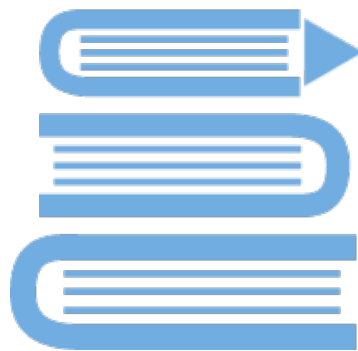


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## Notes

# Notes

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- Organic Chemistry is a big chapter in the chemistry course. It always comes up as one question in section B and an experiment in section A of the exam. As well as that there may be another partial question on it.
- Organic chemistry basically just means chemistry that deals with compounds of Carbon with Hydrogen and Oxygen mostly.

**Hydrocarbon:** A compound that contains only hydrogen and carbon.

**Unsaturated compound :** An organic molecule that has double or triple bonds present.

**Saturated compound:** An organic molecule that has only single bonds.

## Tetrahedral vs Planar

- Going back to the shapes of molecules (which we looked at in Q5).
- Tetrahedral basically means that the molecule is 3D, this occurs in saturated compounds, i.e. compounds with single bonds.
- Planar means that the molecule is flat, this occurs in unsaturated compounds, i.e. when the compound has double or triple bonds.

## Aromatic and Aliphatic compounds

- Aromatic compounds have a benzene ring present.
- Aliphatic compounds do not have a benzene ring present.

**Homologous Series :** A family of organic compounds with the same general formula, similar chemical properties and each successive member differs by  $\text{CH}_2$ .

There are 8 different Homologous series on the course.

- Alkanes
- Alkenes
- Alkynes
- Alcohols
- Ketones
- Carboxylic acids
- Aldehydes
- Esters

Before we talk about them we have to know a few other things.

This next explanation seems more complicated than it is, however look at the examples given and it should become clear.

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## IUPAC naming of compounds

1. The first thing you need to do when finding the name of a compound is finding the homologous series that it belongs to. Do this by looking if it has single, double or triple bonds. You can also look out for

oxygen in the compound.

Whichever series this belongs to, this will give the end of the compound its name. ie. It will end in -ane, -ene, -yne etc.

1. Next you have to look for the longest chain of carbons in the compound. Whichever number this gives will give you the middle of the name of the compound. For example if we know it is an alkane, we will count the longest chain of carbons, if this number is 6, then we know that the middle bit will be -hex-.
2. Then you will have to look for alkyl subgroups. These alkyl subgroups are branches that branch off the main chain of carbons. You have to count how many carbons are in the branch, and then name the alkyls accordingly.
3. Finally you will have to see where the subgroups branch off, depending where on the main chain of carbons they branch off they will be assigned a different number.

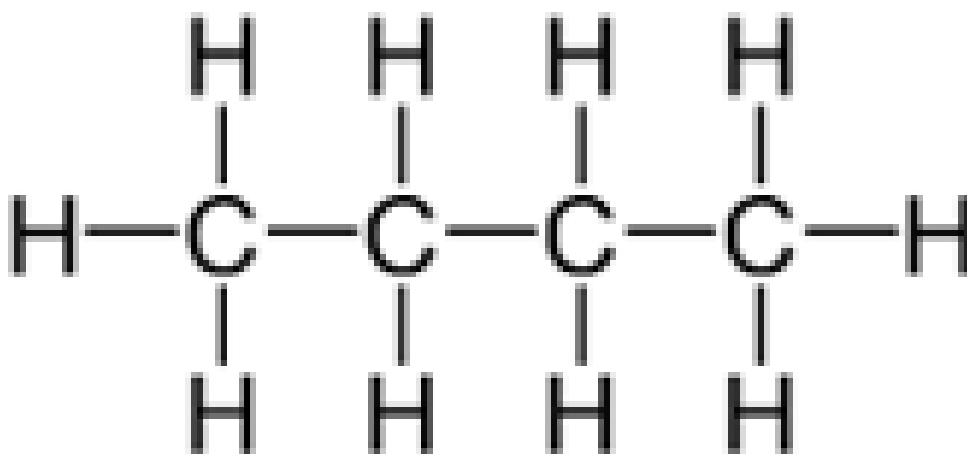


Prefix	Number of Carbons
Meth-	1
Eth-	2
Prop-	3
But-	4
Pent-	5
Hex-	6
Hept-	7
Oct-	8



Alkyl Subgroup	Number of Carbons	Structure
Methyl-	1	$\begin{array}{c} \text{H} \\   \\ -\text{C}-\text{H} \\   \\ \text{H} \end{array}$
Ethyl-	2	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ -\text{C}-\text{C}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$
Propyl-	3	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\   \quad   \quad   \\ \text{H}-\text{C}-\text{C}-\text{C}- \\   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$

### Example 1



**Name the above organic compound.**

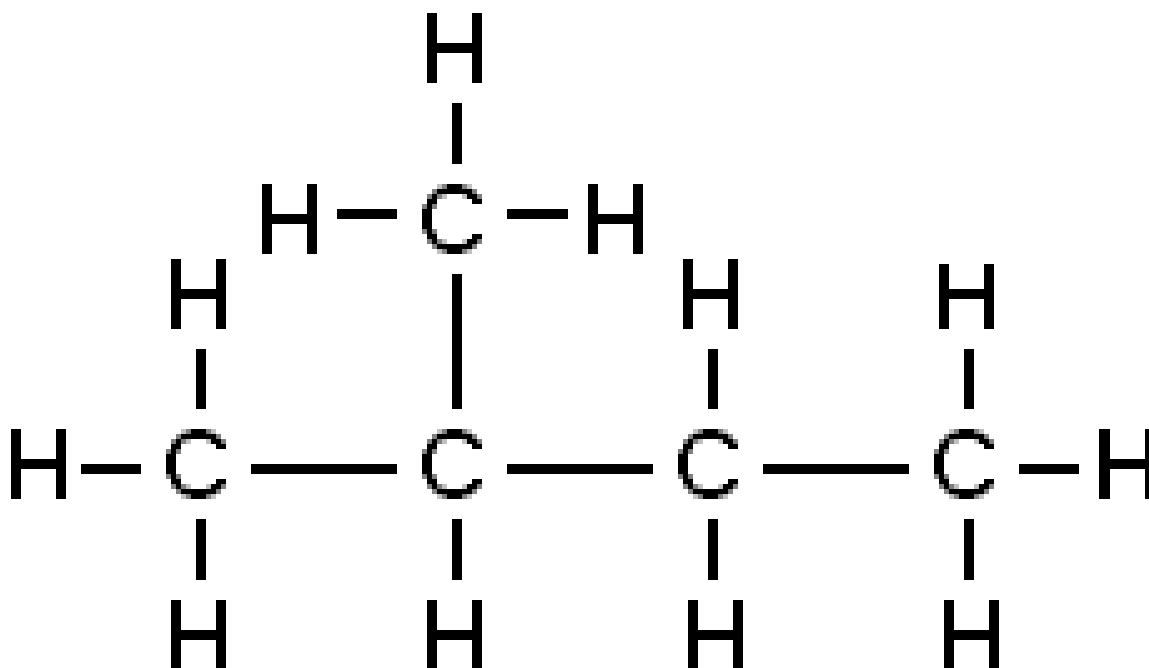
Ok so we are going to follow the steps.

1. Which series does it belong to? It is a straight chain molecule, with only single bonds between hydrogen and carbon. This means it is an Alkane. So the ending will be -ane.
2. The longest chain of carbons in the molecule is 4. Therefore the middle bit will be -but-.
3. There are no branches/subgroups, so this point doesn't apply.
4. Since there are no branches, this point doesn't apply either.

We are left with the following: **butane**. So that is the name for the above molecule.

### Example 2

This example will be a little bit harder.



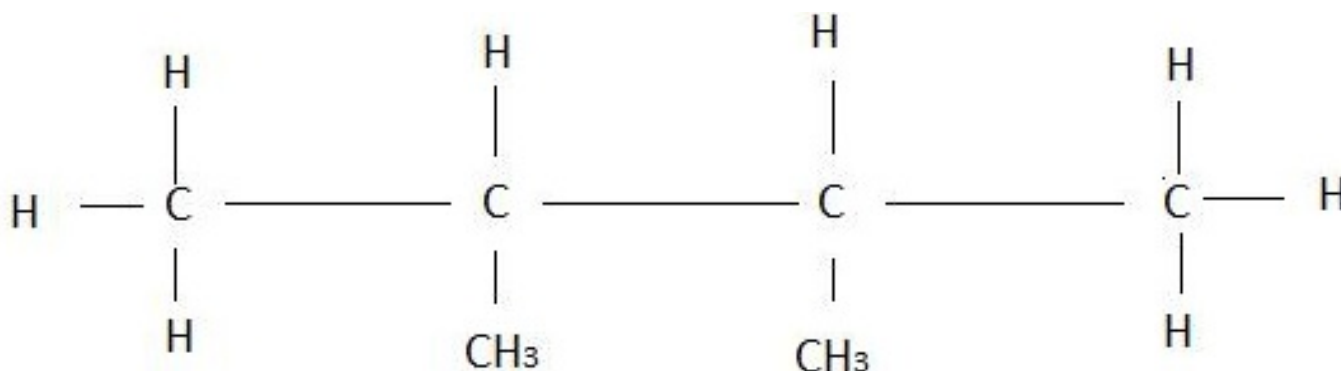
Again we will follow the steps.

1. Again it is only single bonds between carbon and hydrogen atoms. Alkane, ending -ane.
2. The longest chain is 4 carbons in a row. Middle bit: -but-
3. There is one branch. It has only one carbon in it. Therefore it is called methyl
4. Now the methyl branch occurs on the second carbon from the left, therefore the number we assign it is 2. (You could also argue that it is on the third carbon from the right, however we always choose the lowest number.)

Now here is how we put all of those bits together:

### 2-methylbutane

#### Example 3



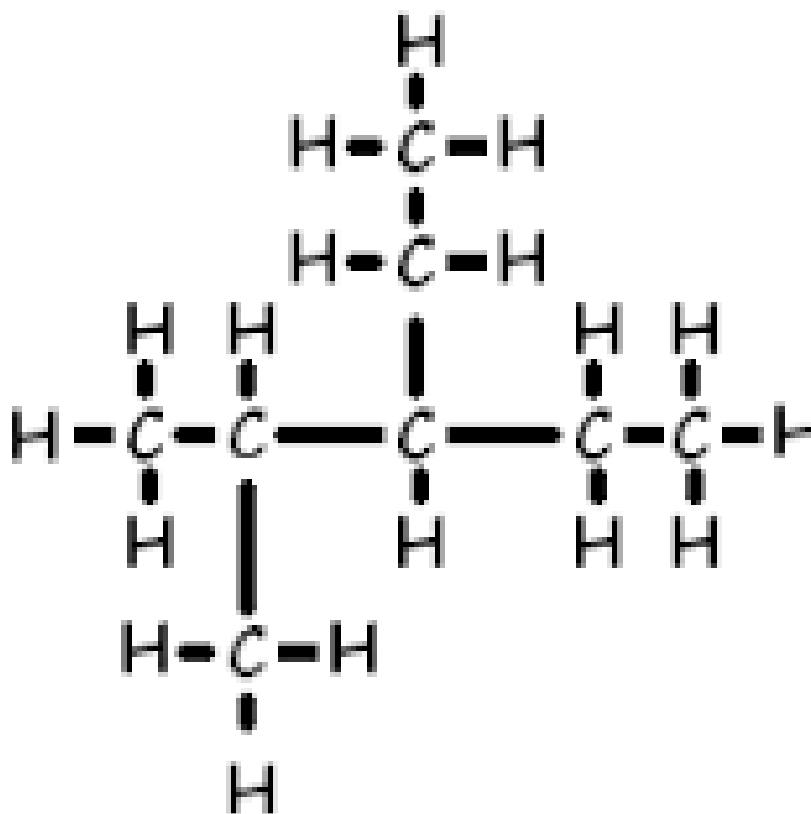
1. Again it is only single bonds between carbon and hydrogen atoms. Alkane, ending -ane.
2. The longest chain is 4 carbons in a row. Middle bit: -but-
3. There are two branches. They both have 1 carbon in them. Therefore they are called methyl.
4. Now the methyl branches occur on the second carbon and the third carbon. Therefore the number for the first branch is 2 and the number for the second branch is 3.

Now here is how we put all of those bits together:

### 2,3-dimethylbutane

- (note that we put commas between numbers and hyphons between numbers and letters, also the di indicates that there are two methyl subgroups.)

#### Example 4



1. Again it is only single bonds between carbon and hydrogen atoms. Alkane, ending -ane.
2. The longest chain is 5 carbons in a row. Middle bit: -pent-
3. There are two branches. The first branch has one carbon, therefore methyl. The second branch has 2 carbons, therefore is called ethyl.
4. Now the methyl branch occurs on the second carbon. Therefore the number for the methyl branch is 2. The ethyl branch occurs on the third carbon so the number for the ethyl branch is 3.

To piece that all together:

**2-methyl-3-ethylpentane.**

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## Homologous Series

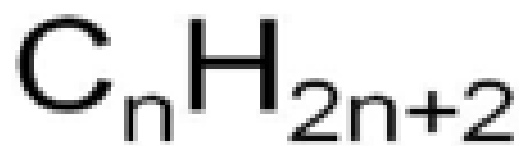
You don't need to know an awful lot about each series, the main things to know are the following:

- Name
- General Formula
- Polar or Non-Polar
- Tetrahedral or Planar (also saturated or unsaturated)
- Functional Group
- Uses

## Alkanes

- The Alkanes are the simplest homologous series on the course.

General Formula:



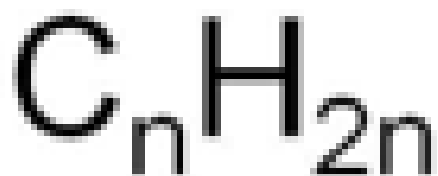
- Non-polar, because of symmetry.
- Tetrahedral because of single bonds. Also implies saturated because of single bonds.
- Functional Group is the C-H bond, (not really a functional group compared to the other ones)
- Uses: Methane is used as natural gas, and the bigger alkanes are used as petrol and fuel for loads of other things.

Name	Formula	Structure	State (at room temp.)
Methane	$\text{CH}_4$	<pre>       H         H - C - H               H           </pre>	Gas
Ethane	$\text{C}_2\text{H}_6$	<pre>       H H           H - C - C - H                 H H           </pre>	Gas
Propane	$\text{C}_3\text{H}_8$	<pre>       H H H             H - C - C - C - H                   H H H           </pre>	Gas
Butane	$\text{C}_4\text{H}_{10}$	<pre>       H H H H               H - C - C - C - C - H                     H H H H           </pre>	Gas
Pentane	$\text{C}_5\text{H}_{12}$	<pre>       H H H H H                 H - C - C - C - C - C - H                       H H H H H           </pre>	Liquid
Hexane	$\text{C}_6\text{H}_{14}$	<pre>       H H H H H H                   H - C - C - C - C - C - C - H                         H H H H H H           </pre>	Liquid

## Alkenes

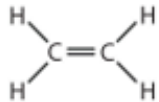
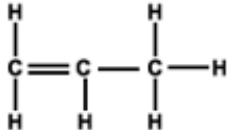
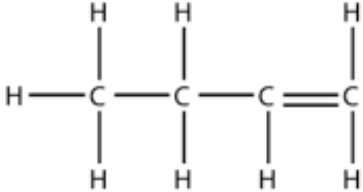
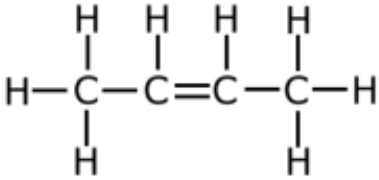
General Formula:





- Non-polar, because of symmetry. - Planar because of double bond Carbon-Carbon. (unsaturated) - Functional Group is the C-C double bond, this means that the C-C is the bit of the molecule that reacts with other molecules during a reaction. - Uses: Ethene gas can be turned into Polythene which is a type of polymer or plastic. This is done through a process called Polymerisation.

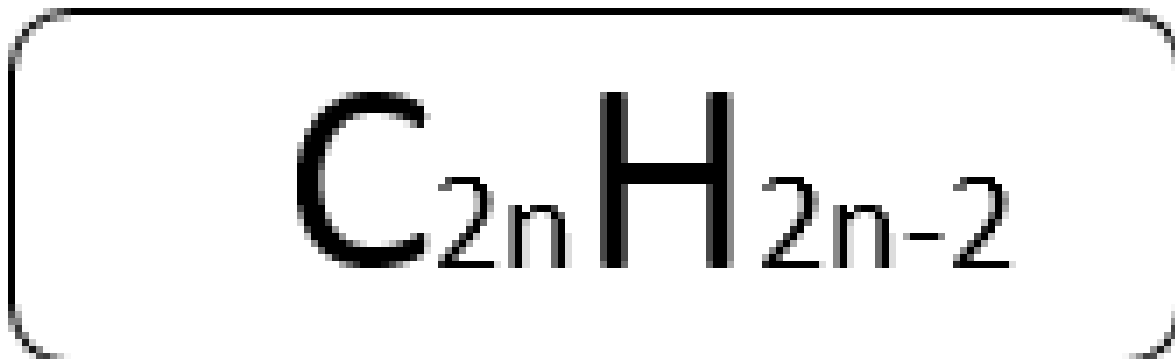
Note: there is no meth- compound of alkene, it starts with two carbons always.

Name	Formula	Structure
Ethene	$C_2H_4$	
Propene	$C_3H_6$	
But-1-ene	$C_4H_8$	
But-2-ene	$C_4H_8$	

But-1-ene and But-1-ene are structural isomers of each other.

## Alkynes

General Formula:



- Non-Polar because of symmetry.
- Planar because of triple bond between hydrogens. (unsaturated)
- Functional Group: Triple Bond Carbon-Carbon.
- Uses: Ethyne is used for welding.
- There is no meth- compound of Alkynes. It starts with two carbons always.



- Ethyne is the only compound that you really need to know the structure of.

## Alcohols

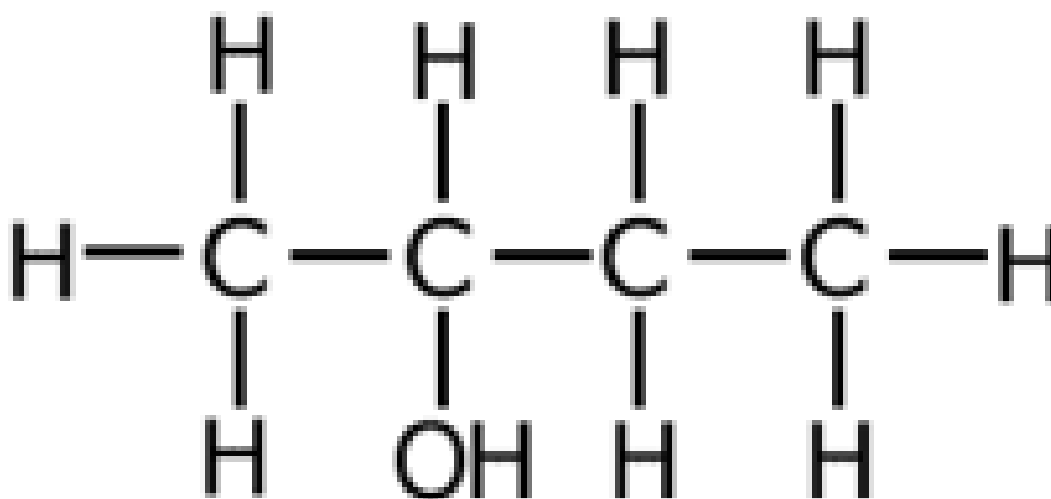
General Formula:



- Polar because of the O-H group.
- Tetrahedral, all single bonds.
- Functional group: O-H, hydroxyl.
- Uses: Ethanol is used for drinking (alcohol), and as a solvent for perfumes.

Name	Formula	Structure
Methanol	CH <sub>3</sub> OH	<pre>       H         H - C - O - H               H           </pre>
Ethanol	C <sub>2</sub> H <sub>5</sub> OH	<pre>       H H           H - C - C - O - H                 H H           </pre>
Propanol	C <sub>3</sub> H <sub>7</sub> OH	<pre>       H H H             H - C - C - C - O - H                   H H H           </pre>
Butanol	C <sub>4</sub> H <sub>9</sub> OH	<pre>       H H H H               H - C - C - C - C - O - H                     H H H H           </pre>

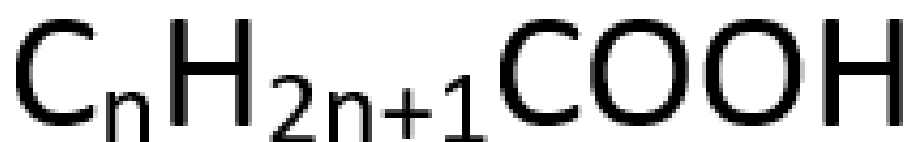
- Technically the names for propanol and butanol above, should be propan-1-ol and butan-1-ol.
- This is because the functional group OH is on the first carbon. This means that they are examples of primary alcohols.
- A secondary alcohol would be when the OH group is on a carbon in the middle of the chain.



Butan-2-ol is shown above.

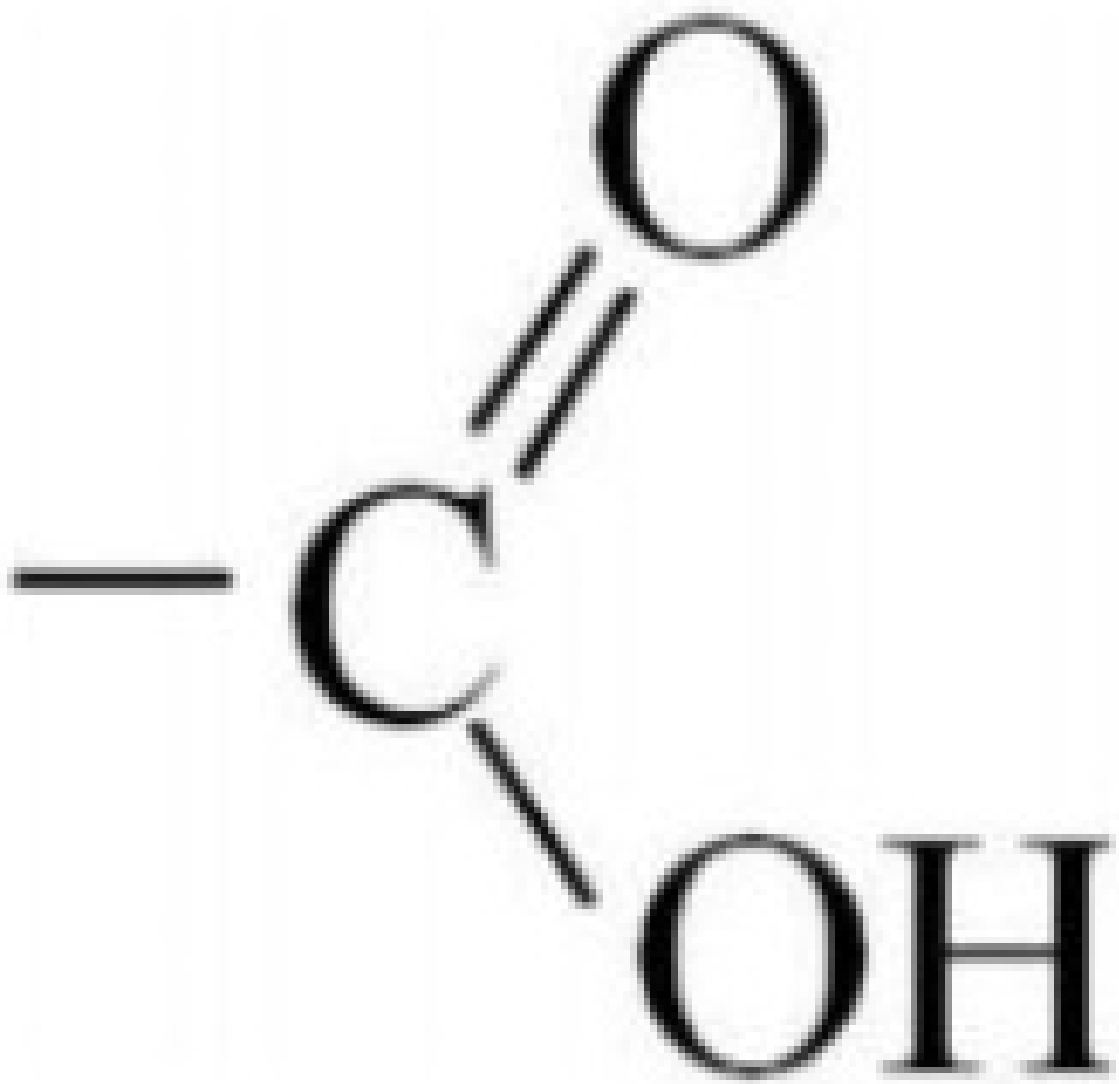
## Carboxylic Acids

General Formula:



- Polar, OH group and the C-O double bond.
- The carbon-carbon bonds are tetrahedral, however the C-O bond is a double bond and is planar. So some parts of the molecule are tetrahedral and some parts are planar.

Functional group: the carboxyl group -

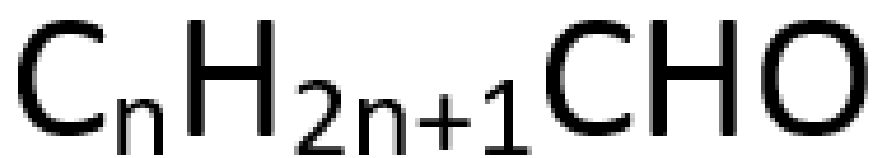


- Uses: Methanoic acid found in nettle and ant stings, Ethanoic acid is the main ingredient in vinegar.

Name	Formula	Structure
<u>Methanoic Acid</u>	HCOOH	$\begin{array}{c} \text{O} \\ \parallel \\ \text{H}-\text{C}-\text{OH} \end{array}$
Ethanoic Acid	CH <sub>3</sub> COOH	$\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{C} \\   \quad \parallel \\ \text{H} \quad \text{O} \\ \quad \quad   \\ \quad \quad \text{OH} \end{array}$
Propanoic Acid	C <sub>2</sub> H <sub>5</sub> COOH	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{C}-\text{C} \\   \quad   \quad \parallel \\ \text{H} \quad \text{H} \quad \text{O} \\ \quad \quad \quad   \\ \quad \quad \quad \text{O}-\text{H} \end{array}$

## Aldehyde

General Formula:



- Functional Group: CHO
- Polar
- Planar, double bond with oxygen.
- Uses: Benzaldehyde - almond essence.

Name	Formula	Structure
<u>Methanal</u>	HCHO	$\begin{array}{c} \text{O} \\ \parallel \\ \text{H}-\text{C}-\text{H} \end{array}$
<u>Ethanal</u>	CH <sub>3</sub> CHO	$\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{C} \\   \quad \quad \parallel \\ \text{H} \quad \quad \text{O} \\ \quad \quad \quad   \\ \quad \quad \quad \text{H} \end{array}$
<u>Propanal</u>	C <sub>2</sub> H <sub>5</sub> CHO	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{C}-\text{C} \\   \quad   \quad \parallel \\ \text{H} \quad \text{H} \quad \text{O} \\ \quad \quad \quad   \\ \quad \quad \quad \text{H} \end{array}$

## Ketones

General Formula:



- In this case R isn't an element, R stands for alkyl groups. This means that they are of the general formula  $\text{C}_n\text{H}_{2n+1}$ . So for example they could be CH<sub>3</sub> or C<sub>2</sub>H<sub>5</sub> or C<sub>3</sub>H<sub>7</sub> etc. R<sub>1</sub> and R<sub>2</sub> are there just to show that they might be different, they can be the same also though.

- Functional group: C-O double bond
- Polar
- Planar
- Uses: Propanone=Acetone (different name), this is used as nail varnish remover.

Name	Formula	Structure
Propanone	$\text{CH}_3\text{COCH}_3$	<pre>       H   O   H                 H - C - C - C - H                           H           H           </pre>
Butanone	$\text{C}_2\text{H}_5\text{COCH}_3$	<pre>       H   H   O   H                     H - C - C - C - C - H                               H   H           H           </pre>

## Esters

General Formula:



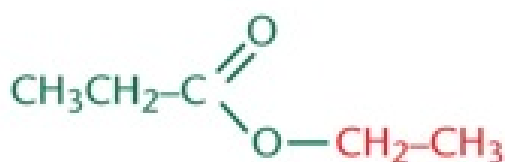
Planar

Polar

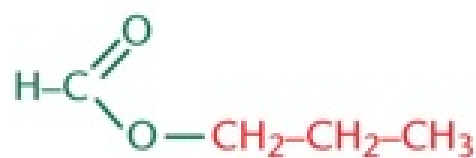
Functional group:  $-\text{COO}-$

- Uses: Fruit smells
- The naming of them is a little bit tricky.
- $\text{R}_2$  gives the first bit of the name.
- And  $\text{R}_1$  gives the second bit.
- The last bit is always -oate.

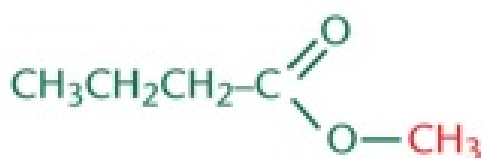




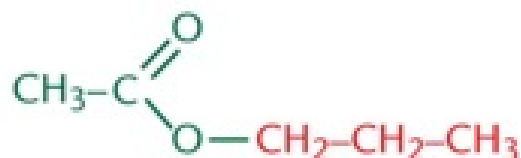
ethyl propanoate



propyl methanoate



methyl butanoate



propyl ethanoate

(don't worry too much about it, they don't come up too often).

Series	Formula	Planar or Tetrahedral	Polar or Non-Polar	Functional Group	Use
Alkane	$\text{C}_n\text{H}_{2n+2}$	Tetrahedral	Non-Polar	C-H	Fuel, Gas
Alkene	$\text{C}_n\text{H}_{2n}$	Planar	Non-Polar	C-C (double)	Plastic
Alkyne	$\text{C}_n\text{H}_{2n-2}$	Planar	Non-Polar	C-C (triple)	Welding
Alcohol	$\text{C}_n\text{H}_{2n+1}\text{OH}$	Tetrahedral	Polar	-OH	Drinking
Carboxylic Acid	$\text{C}_n\text{H}_{2n+1}\text{COOH}$	Planar	Polar	-COOH	Vinegar
Aldehyde	$\text{C}_n\text{H}_{2n+1}\text{CHO}$	Planar	Polar	-CHO	Almond essence
Ketone	$\text{R}_1\text{COR}_2$	Planar	Polar	C-O (double)	Nail Varnish remover
Ester	$\text{R}_1\text{COOR}_2$	Planar	Polar	-COO-	Fruit smell

## Organic Chemical Reactions

- There are a few different types of organic chemical reactions.

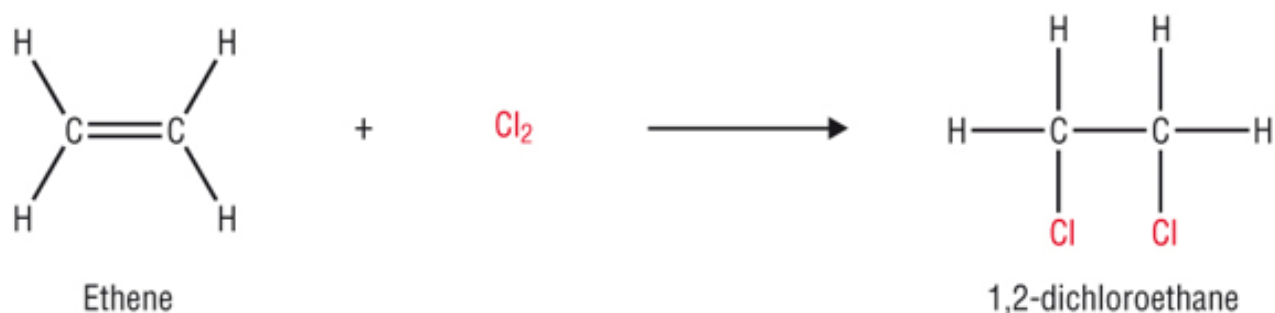
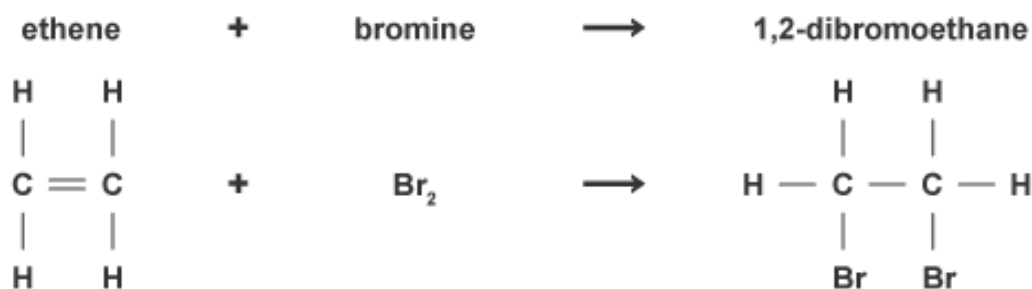
You need to know how these reactions occur and how they turn some of the compounds we have studied above into other compounds from above.

1. Addition Reactions
2. Substitution Reactions
3. Polymerisation
4. Elimination Reactions
5. Redox Reactions

The first two are very commonly asked so make sure to know them well.

# 1. Addition Reactions

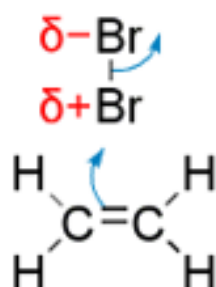
- In addition reactions two small molecules join together to form one larger molecule.
- The reaction is almost always ethene being added to Bromine, Chlorine or HCl.



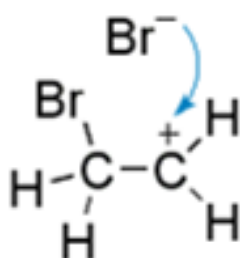
## Reaction Mechanism for addition of Bromine to ethene:

(you can use this for HCl and for Chlorine too, this is normally the 12-15 mark question on exam)

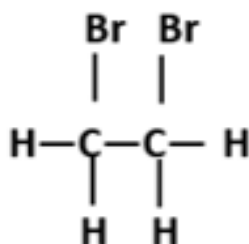
- First step is the polarisation of the Bromine molecule. Because the double bond between the carbons has two electrons, it has a strong negative charge, this then polarises the Bromine molecule because the electrons in the Bromine molecule try to get as far away as possible, leaving one side positive and one side negative.



- The next step is that the Bromine bond breaks, this is called hetrolytic fission.
- Then one of the bromine atoms joins the ethene molecule.



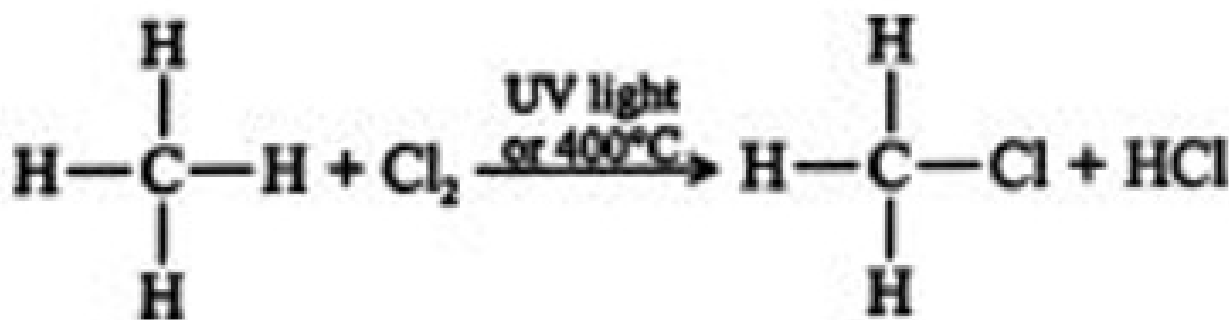
- This forms a localised carbonium ion.
- The second Bromine then joins the carbonium ion to finish the reaction and to make 1,2-dibromoethane.



## 2.Substitution Reactions

- As the reaction says, in this kind of reaction one atom from a molecule is replaced with another atom from outside.
- The main reaction that we study on this course is the halogenation of alkanes, or in simpler terms. The substitution of chlorine with hydrogen in a methane molecule. This is done with the aid of U.V. (ultraviolet) light.

This type of reaction is called free radical substitution because there are free radicals which means there are atoms with unpaired electrons.



## Reaction Mechanism:

There are 3 steps to the reaction:

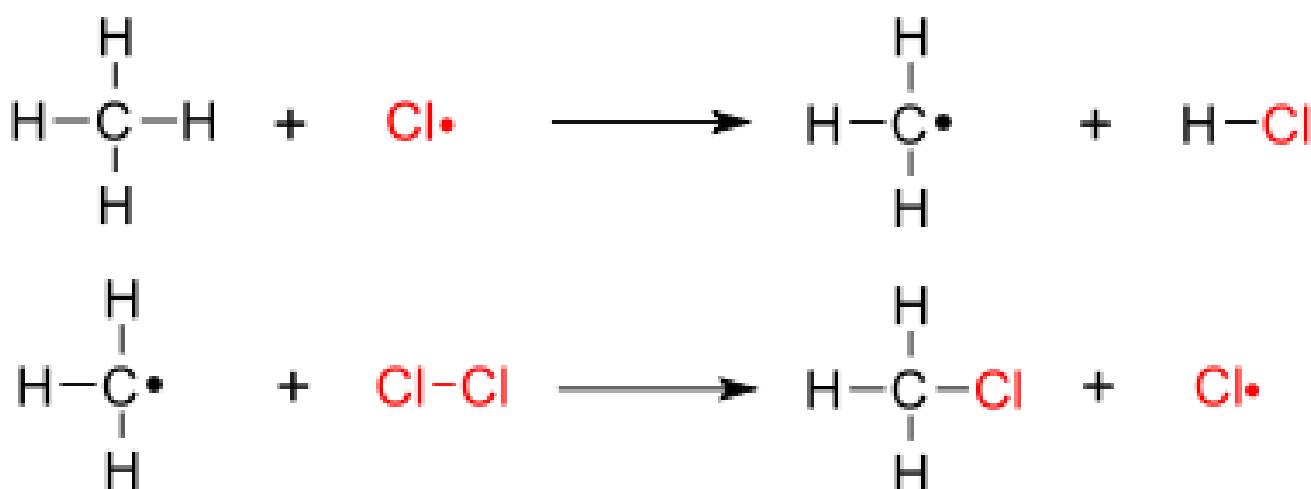
1. Initiation
2. Propagation
3. Termination

### 1. Initiation

- The first step of the reaction is that the UV light added, breaks the chlorine molecules up into two identical chlorine free radical atoms. This is called homolysis/homolytic splitting.
- These are highly reactive because of their unpaired electron

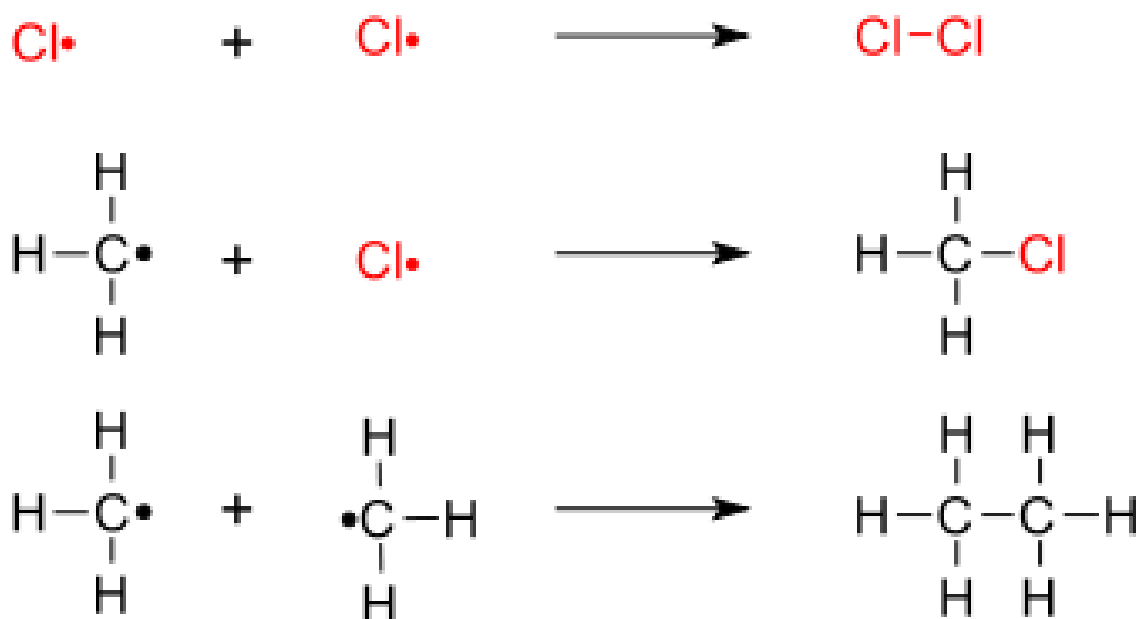
### 2. Propagation

- The chlorine free radicals react with the methane molecules to form Hydrogen Chloride (HCl) and methyl free radicals ( $\text{CH}_3(\cdot)$ ).
- Methyl radicals react with chlorine molecules to form chloromethane and a chlorine radical.
- These two propagation reactions can be seen in the diagram below, This is a chain reaction.



### 3. Termination

- Combination of the remaining radicals to form molecules (chlorine, chloromethane, ethane)

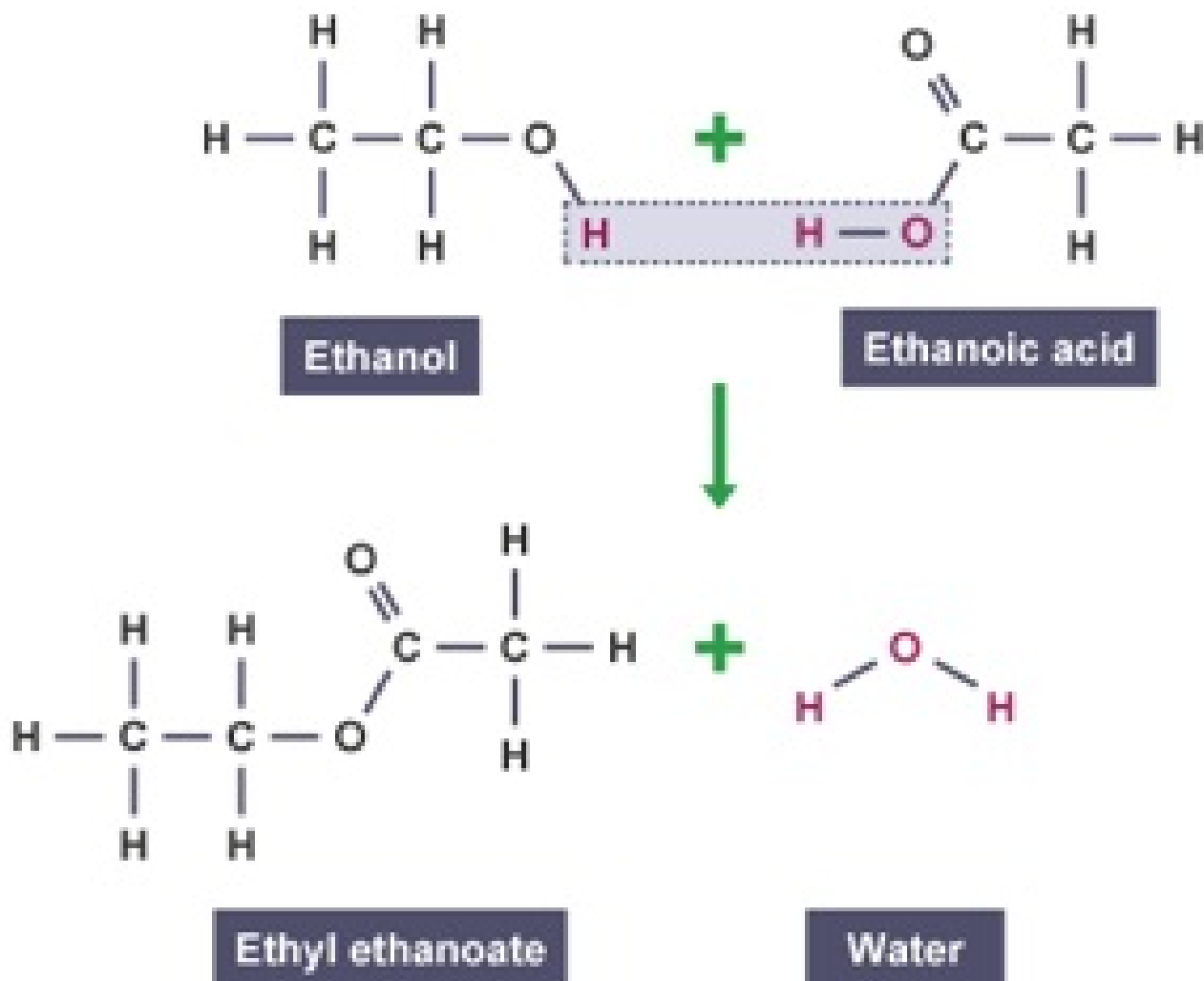


(They can ask this question with ethane and Chlorine as well, you just need to tweak the answer a tiny bit to say ethane instead of methane, the method is the same)

- Be sure to include key words, and to always include dots when drawing the radicals or else you will lose marks.

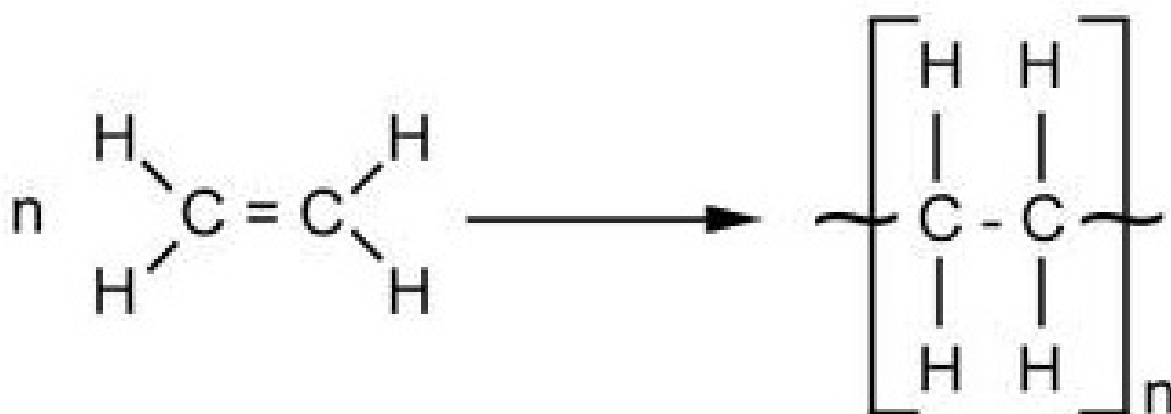
### Esterification

The other substitution reaction on the course is esterification.



### 3. Polymerisation

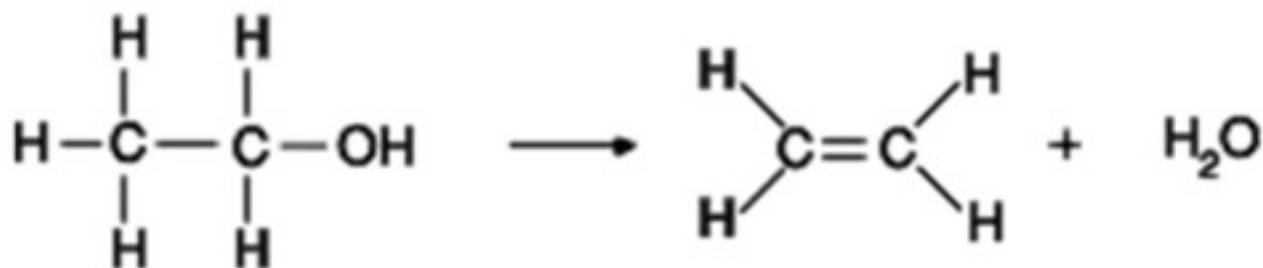
**Polymer:** A very long molecule made up of many identical repeating units called monomers.



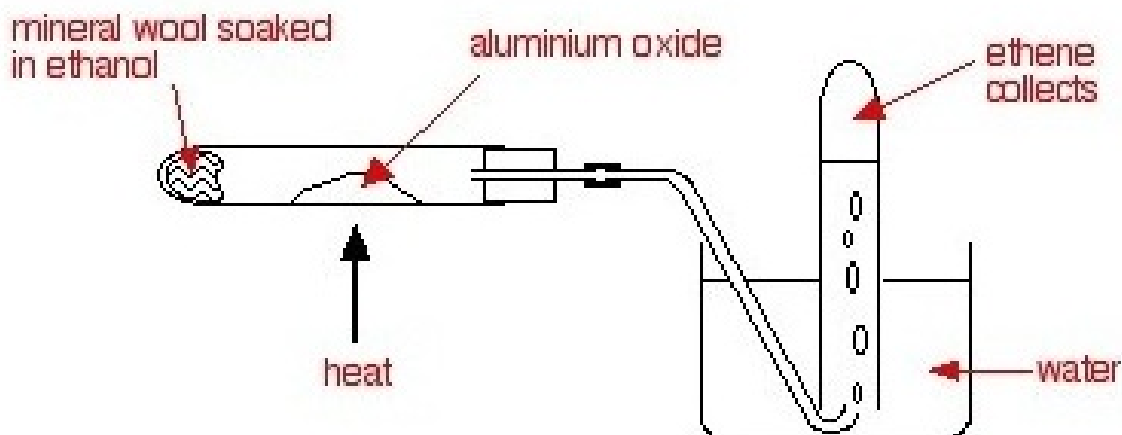
- Many ethene molecules (on the left), are put under heat, pressure and a catalyst is used to create a large repeating molecule on the right called polythene.

## 4. Elimination Reactions

- This is where a small molecule is removed from a saturated compound to form an unsaturated compound. The example on this course mostly is turning ethanol into ethene by removing a water molecule.
- This is also called a dehydration reaction.
- This is basically the opposite of an addition reaction.



This reaction is done with heat and  $\text{Al}_2\text{O}_3$  as a catalyst.



We will look at this experiment in more detail in question 2.

## 5. Redox reactions (Reduction and Oxidation)

**Oxidation** : loss of electrons, or an increase in oxidation number

- Basically, if you add oxygen to something, you are oxidising it.

**Reduction** : gain of electrons, or a decrease in oxidation number

- Basically, if you take away oxygen, or if you add hydrogen.

**Oxidising agent** : allows oxidation to occur

- Example:  $\text{Na}_2\text{Cr}_2\text{O}_7$  mixed with  $\text{H}_2\text{SO}_4$  - sodium dichromate mixed with sulfuric acid.

**Reducing agent** : allows reduction to occur.

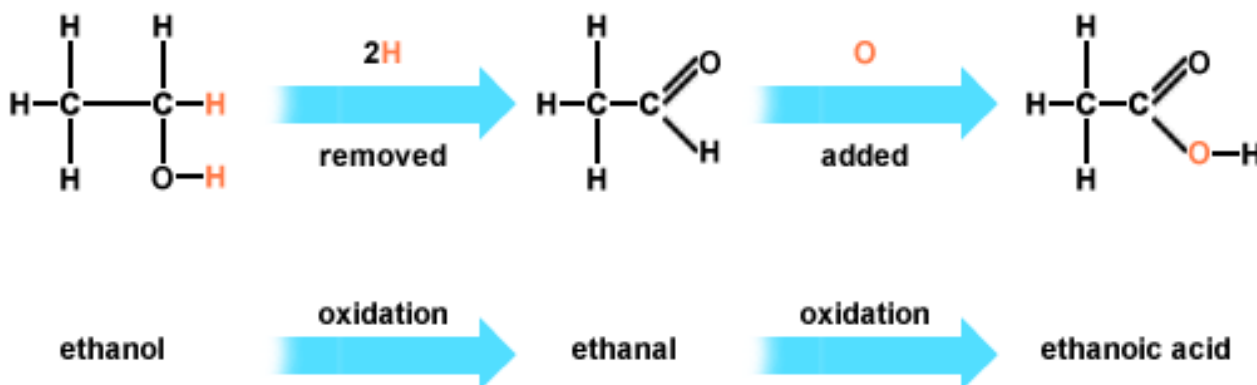
- Example: Ni - Nickel
-

# Oxidation Reaction

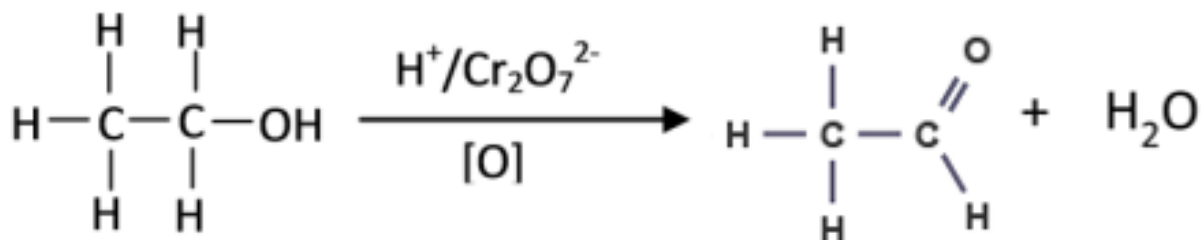
There is one oxidation reaction on the course, but it is split into two parts.

- Ethanol to Ethanal to Ethanoic Acid

Depending on how long you let the reaction go on for you can get either ethanal or ethanoic acid when you let ethanol be oxidised.

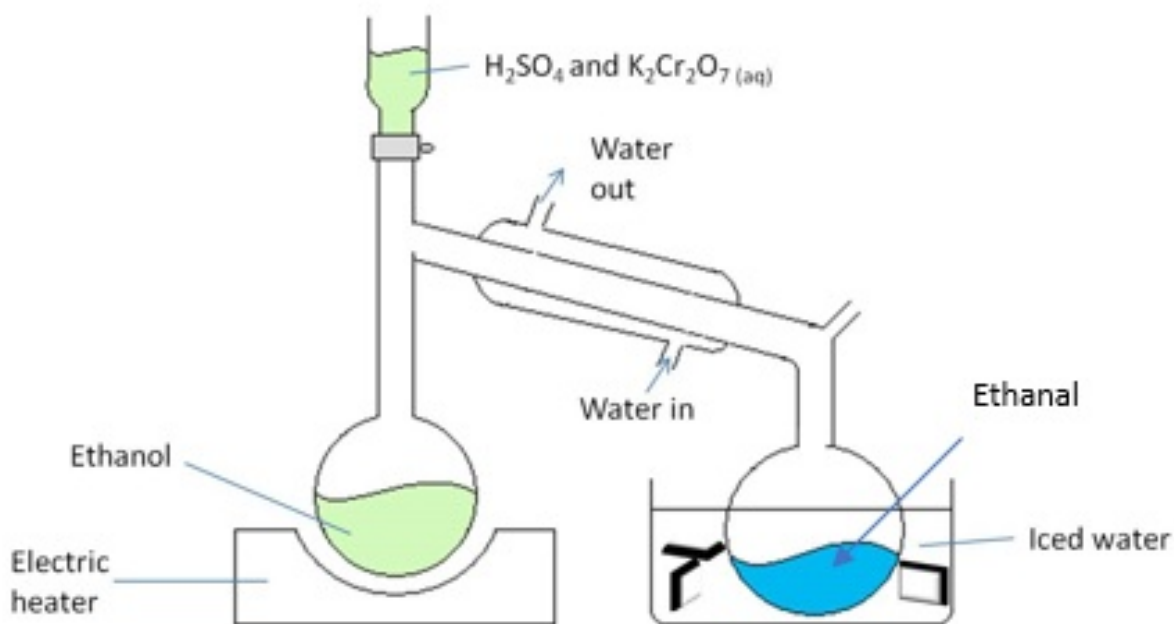


## Ethanol to ethanal



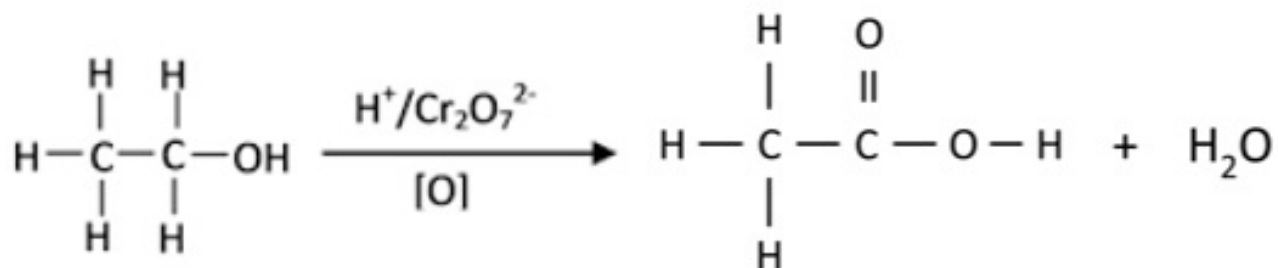
H<sup>+</sup> means H<sub>2</sub>SO<sub>4</sub>, and Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup> means Na<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>. It's just an easier way of writing it.





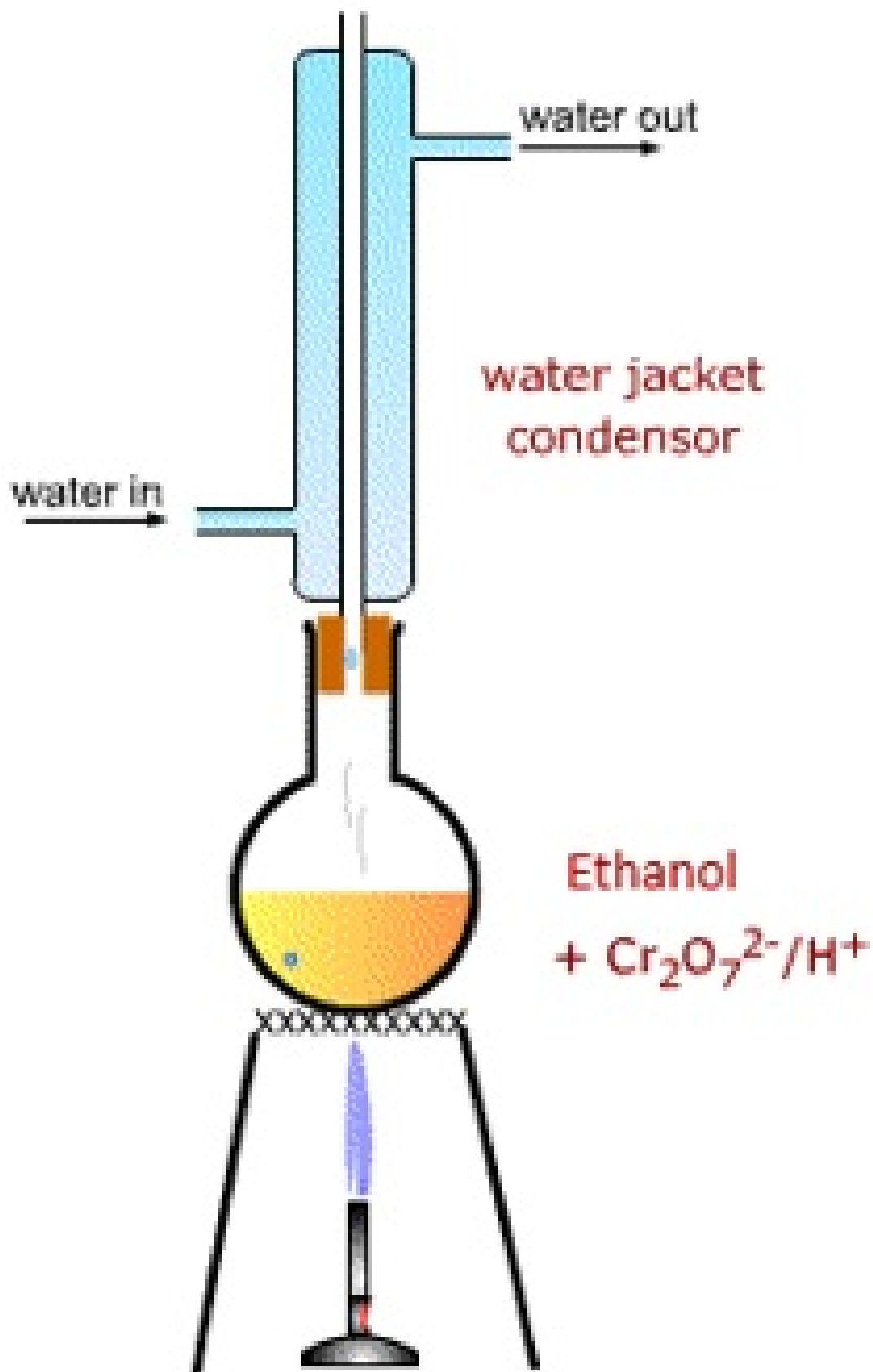
Again we will look at this in more detail in Question 2.

## Ethanol to Ethanoic Acid



- Notice that it is the exact same reactants as the previous equation.

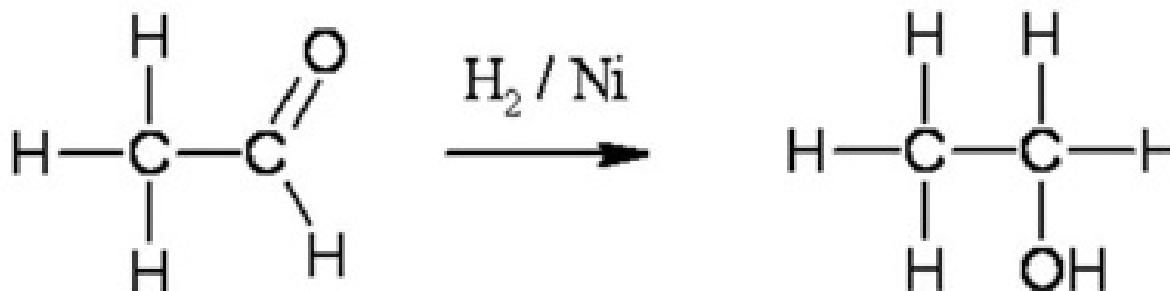
However the experiment is slightly different, it is called a reflux process. All of the evaporated ethanal rises and then is condensed and falls back into the boiling flask to continue reacting, instead of being collected in a conical flask like in the last experiment.



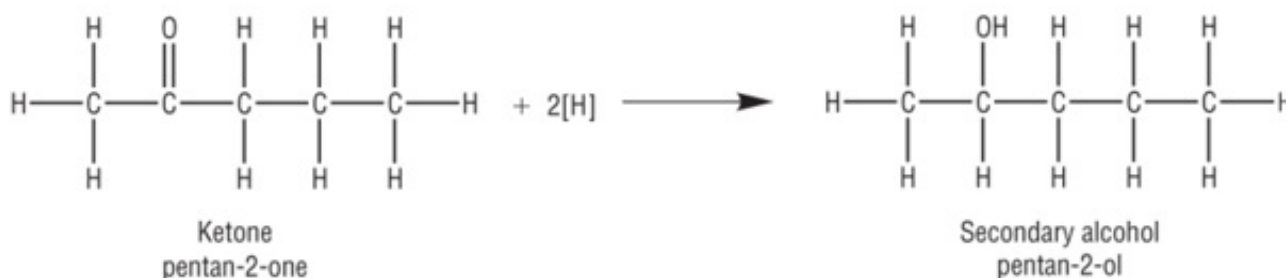
Again this will be looked at in more detail in question 2.

## Reduction Reaction

- The first reduction reaction that is on the course is the reduction of **ethanal to ethanol**. This is the exact opposite of what the first oxidation reaction was. (the first oxidation reaction was ethanol to ethanal)



- The second reduction reaction is the reduction of **secondary alcohols to ketones**. Remember the difference between secondary and primary alcohols is to do with where the OH group is.

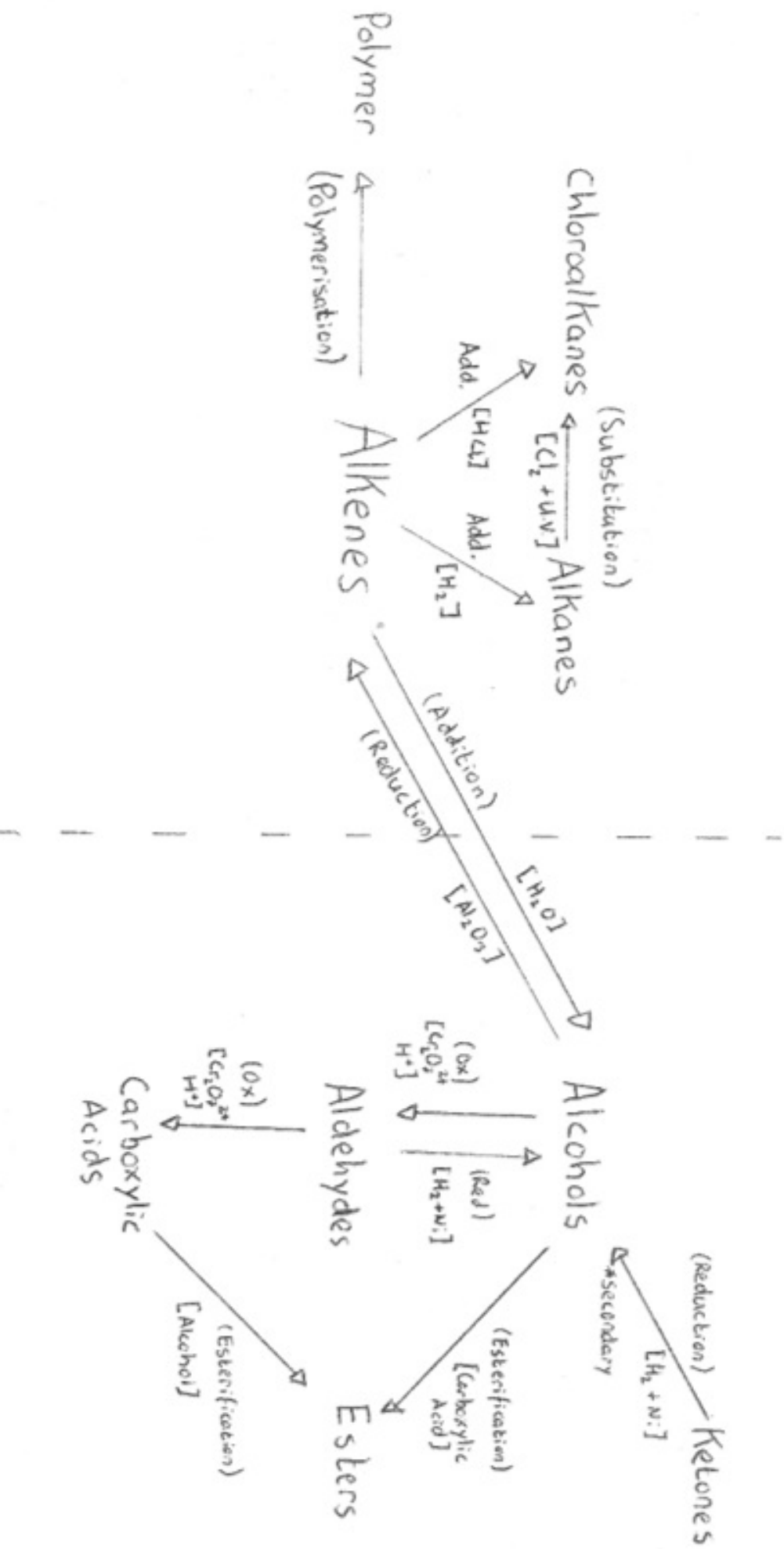


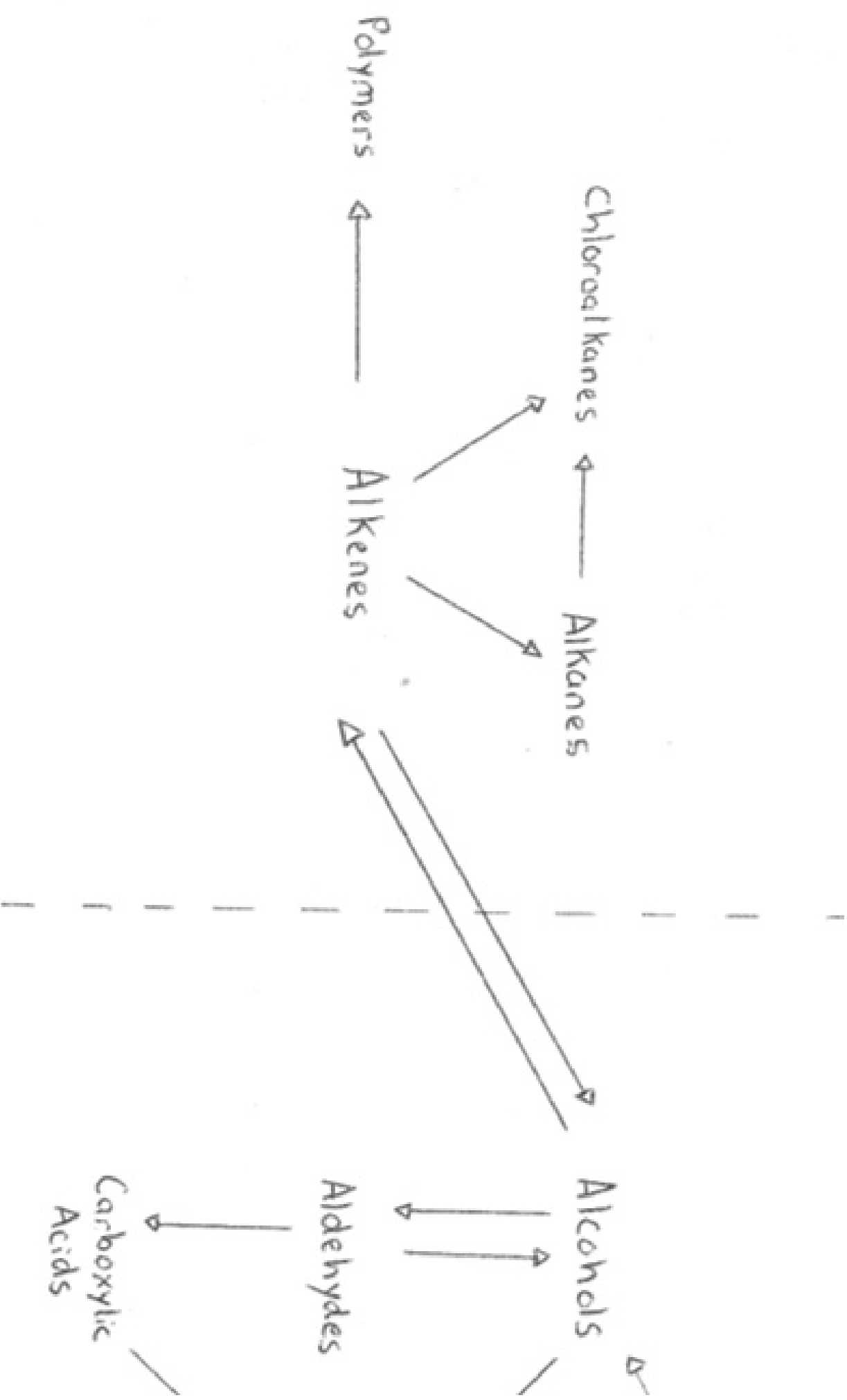
Ketones can be very difficult to oxidise.

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### Summary of the Organic Chemical reactions

- Each reaction on its own shouldn't be too difficult. The most difficult thing to remember is how they are all interrelated, and how they turn into each other and by what reaction they do that.
- We focused on specific molecules when we were studying these reactions, for example ethanol ethanal. However in the exam they could ask about propanol The experiment is the exact same for both.
- For the summary we are just going to look at the series rather than specific molecules.
- There is no best way to do this, you should do whichever way works best for you. This is what we came up with:
- We split them in half into two separate groups to learn. On the right side it's mostly Redox reactions, on the left side then it is substitution, polymerisation and addition.
- We wrote the type of reaction in circular brackets.
- We wrote the reactants or catalysts used in square brackets.
- We would recommend writing this out again for yourself with colours and in whatever way makes you remember best.





Ketones

Esters