



# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Alkanes Combustion

**REACTANTS:** Alkane and O<sub>2</sub> (oxygen)

**CONDITIONS:** Excess of Oxygen (for complete combustion)

**PRODUCT(S):** Carbon Dioxide and Water

**REACTION TYPE:** Combustion



**NOTES:**

- When excess oxygen is present complete combustion occurs so carbon dioxide and water are the only products.
- Incomplete combustion of alkanes occurs when oxygen becomes a limiting reagent, leading to the formation of carbon monoxide (CO) and solid carbon particulates (soot).





# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

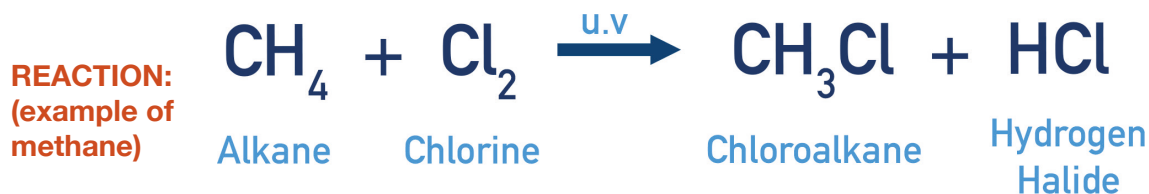
### Alkanes Free Radical Substitution

**REACTANTS:** Alkanes and Halogen

**CONDITIONS:** U.V (ultraviolet) light

**PRODUCT:** Halogenoalkane

**REACTION TYPE:** Free Radical Substitution



**NOTES:**

- Chain reaction, occurring in three steps - **initiation**, **propagation** and **termination**. See *mechanism*.
- U.V light is required to homolytically split halogen molecule, forming two radical species.
- Further substitution can occur, forming di, tri and tetra halogenoalkanes.





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## Reactions for CIE A-Level Chemistry

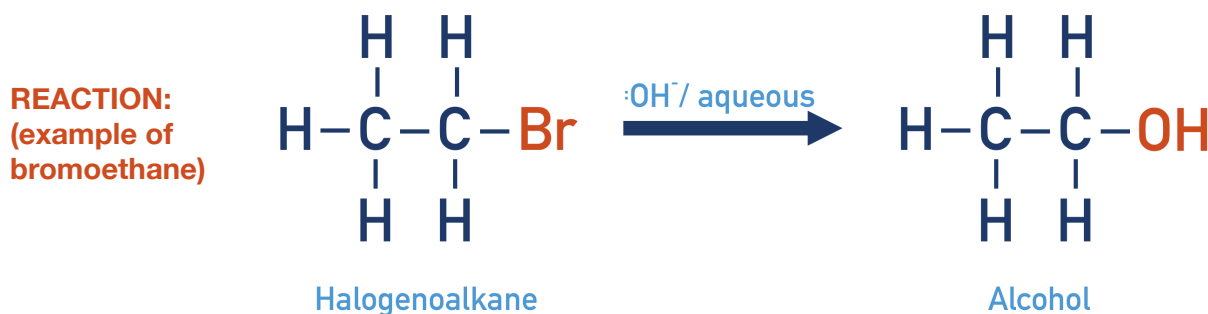
### Halogenoalkanes Substitution ( $\text{OH}^-$ )

**REACTANTS:** Halogenoalkane and Sodium Hydroxide,  $\text{NaOH}$  (for  $\text{OH}^-$  ions)

**CONDITIONS:** Heat under reflux, Aqueous ('aq' - water present)

**PRODUCT(S):** Alcohol and Halide Ion (sodium halide salt if sodium hydroxide used)

**REACTION TYPE:** Nucleophilic Substitution, *Hydrolysis*



**NOTES:**

- Rate of reaction is determined by strength of carbon-halogen bond (carbon-fluorine bond is strongest giving slowest rate; carbon-iodine bond is weakest, giving fastest rate).
- Rate of hydrolysis can be compared using aqueous silver nitrate ( $\text{AgNO}_3$ ) within the reaction mixture and timing how long it takes to form precipitate (Cl = **white** ppt, Br = **cream** ppt and I = **yellow** ppt).
- Reaction must be carried out in **aqueous conditions, otherwise an elimination can occur.**



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## Reactions for CIE A-Level Chemistry

### Halogenoalkanes Substitution (CN<sup>-</sup>)

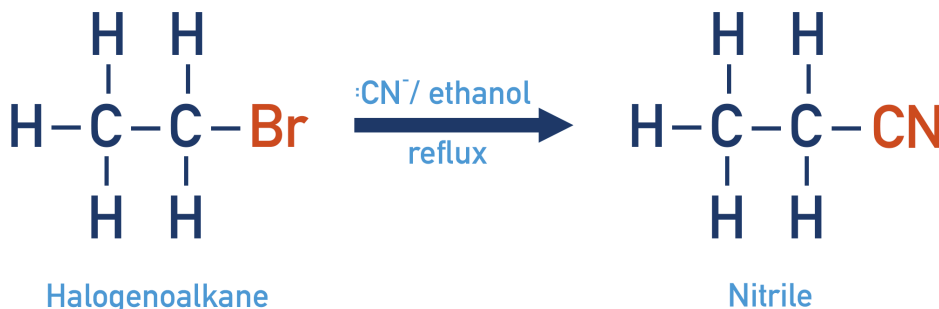
**REACTANTS:** Halogenoalkane and Sodium or Potassium Cyanide (NaCN or KCN)

**CONDITIONS:** Heat under reflux, Ethanolic (ethanol as the solvent, **no water present**)

**PRODUCT(S):** Nitrile and Halide Ion (*forms salt with Na<sup>+</sup> or K<sup>+</sup>*)

**REACTION TYPE:** Nucleophilic Substitution

**REACTION:**  
(example of  
pentane)



**NOTES:**

- Rate of reaction is determined by strength of carbon-halogen bond (carbon-fluorine bond is strongest, giving slowest rate; carbon-iodine bond is weakest, giving fastest rate).
- Reaction must be carried out in **ethanolic conditions (in ethanol, no water present)**, otherwise **an alcohol is likely to form** rather than the nitrile.
- Reaction is heated under reflux to ensure no volatile substances are lost.



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## Reactions for CIE A-Level Chemistry

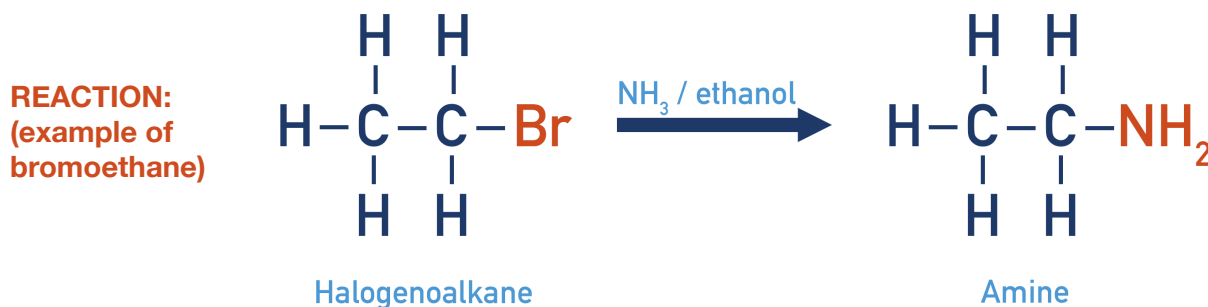
### Halogenoalkanes Substitution ( $\text{NH}_3$ )

**REACTANTS:** Halogenoalkane and Ammonia ( $\text{NH}_3$ )

**CONDITIONS:** Heat\*, Ethanolic (ethanol as the solvent, **no water present**)

**PRODUCT(S):** Amine and Ammonium Halide Salt

**REACTION TYPE:** Nucleophilic Substitution



#### NOTES:

- Reaction must be carried out in **ethanolic conditions (in ethanol, no water present)**, otherwise **an alcohol is likely to form** rather than the amine.
- \*A sealed container (to stop ammonia escaping) containing reactants is heated.
- The amine formed in the reaction is a stronger base than ammonia and an ammonium-alkyl  $[\text{RNH}_3]^+$  salt may be formed. The amine can be obtained by adding sodium hydroxide to the mixture - forcing the alkyl-ammonium ion to 'release' a  $\text{H}^+$  ion and become a neutral molecule.
- Rate of reaction is determined by strength of carbon-halogen bond (carbon-fluorine bond is strongest, giving slowest rate; carbon-iodine bond is weakest, giving fastest rate).



# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Halogenoalkanes Substitution and Elimination ( $\text{OH}^-$ )

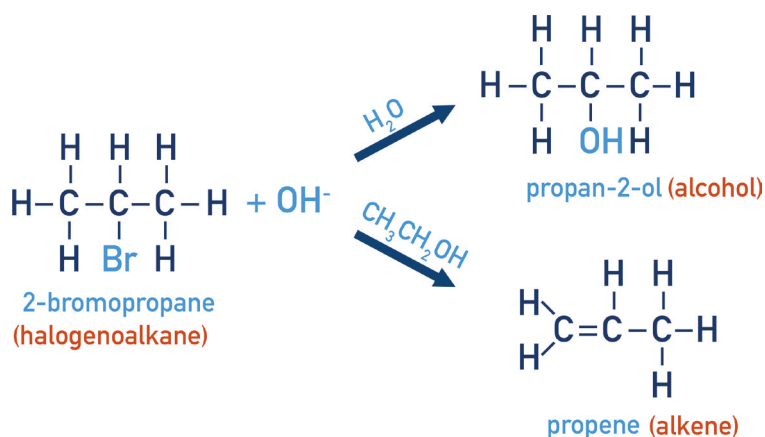
**REACTANTS:** Halogenoalkane and Potassium Hydroxide (for  $\text{OH}^-$  ions)

**CONDITIONS:** Heat under reflux, Ethanolic or Aqueous\*

**PRODUCT(S):** Alcohol **and** Alkene (possible mixture of both)

**REACTION TYPE:** Nucleophilic Substitution **and** Elimination

**REACTION(S):**  
(example of  
2-bromo-  
propane)



#### NOTES:

- Halogenoalkanes can react with hydroxide ( $\text{OH}^-$ ) ions in both substitution and elimination reactions.
- If **substitution occurs an alcohol is formed**, whereas if **elimination occurs an alkene is formed**.
- The solvent used can help ensure more of one product is formed than the other, although final product mixture can still contain both the alcohol and alkene.
- If a hot **aqueous solvent is used, more alcohol forms**.
- If a hot **ethanolic solvent is used, more alkene forms**.
- Primary alcohols are **more likely to undergo substitution** - tertiary alcohols are **more likely to undergo elimination**. Secondary alcohols can undergo both substitution and elimination.
- *Higher temperatures and a more concentrated solution of hydroxide ions favour elimination.*



# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Alkenes Addition (HBr)

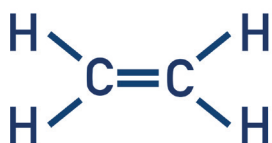
**REACTANTS:** Alkene and Hydrogen Bromide (HBr)

**CONDITIONS:** Hydrogen Bromide Gas or (concentrated) Hydrobromic Acid

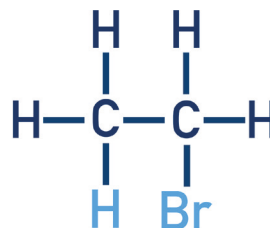
**PRODUCT(S):** Bromoalkane

**REACTION TYPE:** Electrophilic Addition

**REACTION:**  
(example of  
ethene)



Alkene



Bromoalkane

**NOTES:**

- For unsymmetrical alkenes, there will be two possible products from the electrophilic addition.
- Stability of the carbocation intermediate in the mechanism will determine which product will be made more readily (**major product**) and which product will be made less readily (**minor product**). See *mechanism*.





# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Alkenes Addition ( $\text{Br}_2$ )

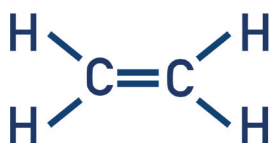
**REACTANTS:** Alkene and Bromine ( $\text{Br}_2$ )

**CONDITIONS:** Bromine Liquid (pure  $\text{Br}_2$ ) or Bromine Water ( $\text{Br}_2(\text{aq})$ )

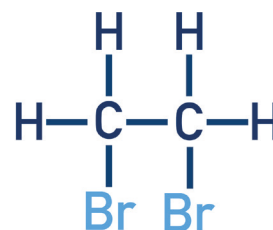
**PRODUCT(S):** Dibromoalkane

**REACTION TYPE:** Electrophilic Addition, *Bromination*

**REACTION:**  
(example of  
ethene)



Alkene



Dibromoalkane

#### NOTES:

- Double bond in alkene polarises the bromine molecule to form an electrophile ( $\text{Br}^{\delta+}$ ) that starts the reaction.
- Reaction can be used to test for the presence of an alkene. A sample is mixed with bromine water, if the bromine water turns colourless (from orange - brown) an alkene is present in the sample.







# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Alkenes Hydration (to alcohol)

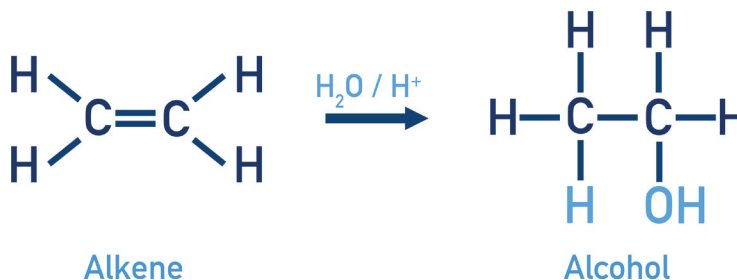
**REACTANTS:** Alkene and Steam ( $\text{H}_2\text{O}_{(\text{g})}$ )

**CONDITIONS:** Heat and Acid Catalyst (Phosphoric Acid,  $\text{H}_3\text{PO}_4$ )

**PRODUCT(S):** Alcohol

**REACTION TYPE:** Electrophilic Addition, (*acid catalysed*) Hydration

**REACTION:**  
(example of  
ethene)



#### NOTES:

- Acid catalyst is required to form hydroxonium ion ( $\text{H}_3\text{O}^+$ ) ion that is able to act as an electrophile to start the reaction.
- For unsymmetrical alkenes, there will be two possible products from the electrophilic addition.
- Stability of the carbocation intermediate in the mechanism will determine which product will be made more readily (**major product**) and which product will be made less readily (**minor product**). See *mechanism*.



# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Alkenes Hydrogenation (to alkane)

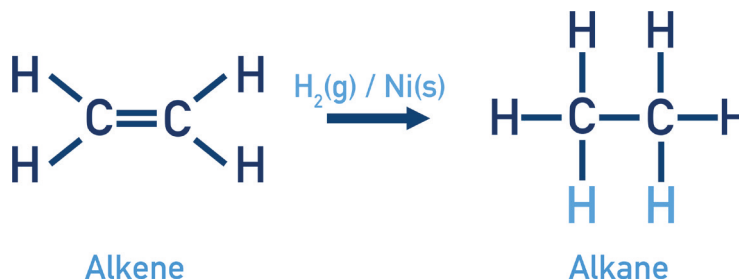
**REACTANTS:** Alkene and Hydrogen,  $H_2$

**CONDITIONS:** Approximately  $150^\circ\text{C}$  and Nickel (solid) Catalyst

**PRODUCT(S):** Alkane

**REACTION TYPE:** Addition, *Hydrogenation*

**REACTION:**  
(example of  
ethene)



**NOTES:**

- Hydrogen is 'added' across the double bond - addition reaction and the hydrocarbon becomes saturated (from unsaturated (alkene)).



# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Alkenes Oxidation (to form diol)

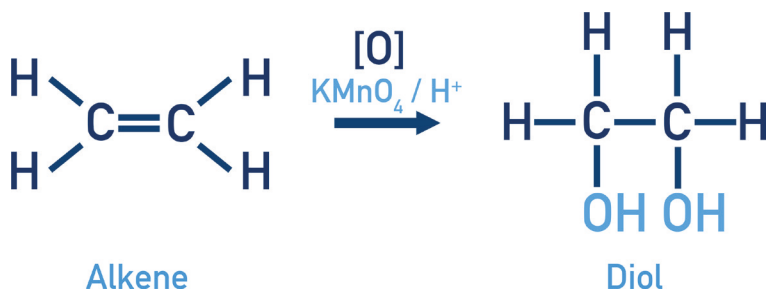
**REACTANTS:** Alkene and (dilute) Potassium Manganate (VII)

**CONDITIONS:** Cold Temperature, Acidic Conditions

**PRODUCT(S):** Diol

**REACTION TYPE:** Oxidation

**REACTION:**  
(example of  
ethene)



#### NOTES:

- Oxidation reaction must be carried out in cold temperature with dilute potassium manganate to ensure the diol doesn't get further oxidised and split in two (forming two carbonyl containing molecules).
- Colour change of the acidified potassium manganate (VII) - (**purple to colourless**), can be used as a test to show a double bond is present (although the bromine water test is simpler and more specific).



# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

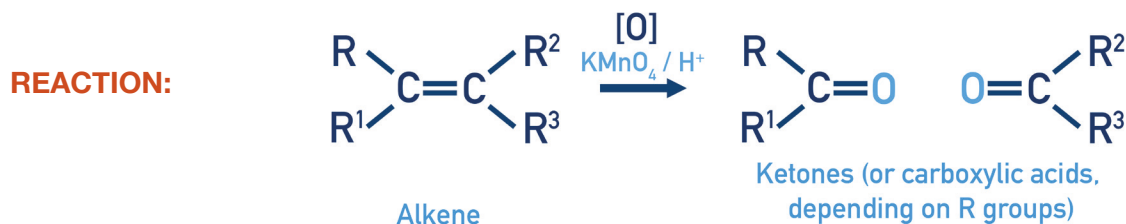
### Alkenes Oxidation (breaking C=C double bond)

**REACTANTS:** Alkene and (concentrated) Potassium Manganate (VII)

**CONDITIONS:** Hot Temperature, Acidic Conditions

**PRODUCT(S):** Two Carbonyl Molecules (split C=C double bond)

**REACTION TYPE:** Oxidation



#### NOTES:

- If concentrated potassium manganate (VII) and a high temperature is used, the carbon double bond in the alkene is broken completely and two new carbonyl groups form (each on a new molecule).
- Depending on the R groups of the original alkene, carboxylic acids can form (if one of the R groups is H) as an aldehyde formed would be further oxidised to a carboxylic acid.



# Organic Chemistry Revision Sheets

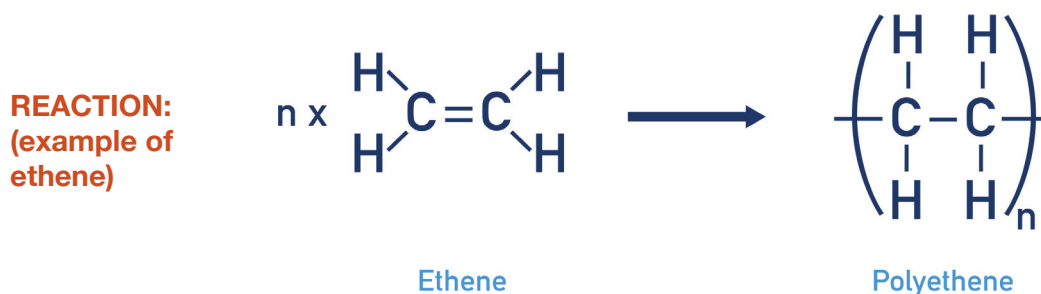
## Reactions for Edexcel A-Level Chemistry

### Polymers Addition (from alkenes)

**REACTANTS:** Alkene

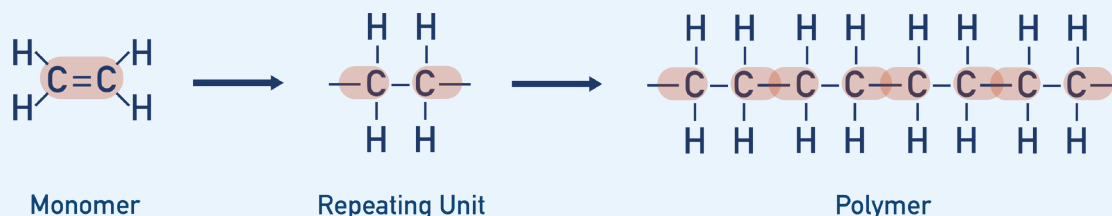
**PRODUCT(S):** Poly(alkene)

**REACTION TYPE:** Addition Polymerisation



#### NOTES:

- The carbon-carbon double bond in the alkene breaks, allowing each carbon atom to form a new bond (with another carbon atom from another molecule).
- The alkenes that form a polymer are called **monomers**.
- The polymer is made up of **repeating units**.





# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Alcohols Oxidation

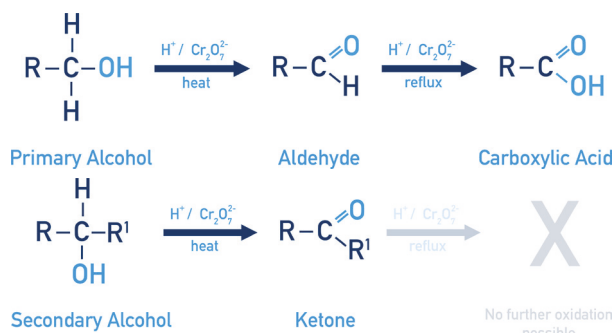
**REACTANTS:** Alcohol (primary or secondary) and Acidified Dichromate ions ( $\text{Cr}_2\text{O}_7^{2-} / \text{H}^+$ )

**CONDITIONS:** Heat\*, Acid Catalyst (sulfuric acid ( $\text{H}_2\text{SO}_4$ ))

**PRODUCT(S):** Aldehyde, Ketone or Carboxylic Acid (see below)

**REACTION TYPE:** Oxidation

**REACTIONS:**  
(example of  
primary and  
secondary  
alcohol)



#### NOTES:

- \*Primary alcohols form aldehydes and carboxylic acids when heated with an oxidising agent. To isolate aldehyde, distill aldehyde from reaction mixture as soon as it is formed. To obtain carboxylic acid, heat under reflux to ensure full oxidation of aldehydes already formed.
- Secondary alcohols form ketones and are unable to be further oxidised. Tertiary alcohols are unable to be oxidised at all.
- Oxidising agents can be represented as [O].



# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Alcohols Halogenation ( $\text{PCl}_5$ )

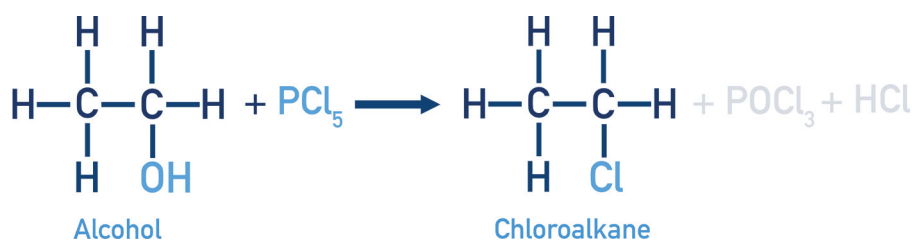
**REACTANTS:** Alcohol and (solid) Phosphorus (V) Pentachloride ( $\text{PCl}_5$ )

**CONDITIONS:** Pure alcohol (no water must be present)

**PRODUCT(S):** Chloroalkane and HCl (white fumes)

**REACTION TYPE:** Halogenation

**REACTIONS:**  
(example of  
ethanol)



**NOTES:**

- $\text{PCl}_5$  reacts vigorously with  $-\text{OH}$  groups, producing white misty fumes of HCl. Due to this, the sample of alcohol being halogenated must be pure containing no water or other molecules with an  $-\text{OH}$  group.
- The reaction can be used to test for an alcohol (positive result is observation of misty white fumes).



# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Alcohols Halogenation (KBr)

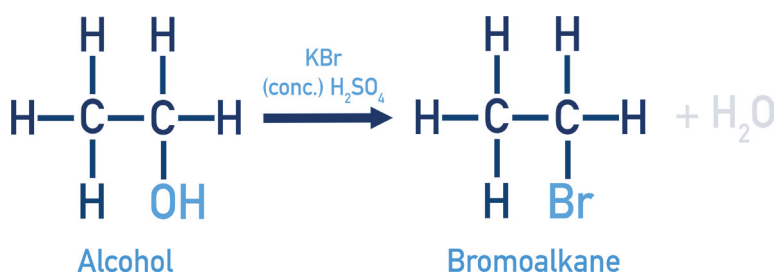
**REACTANTS:** Alcohol and 50% (concentrated)  $\text{H}_2\text{SO}_4$  and Potassium Bromide, KBr

**CONDITIONS:** (concentrated)  $\text{H}_2\text{SO}_4$ , Warm Temperature (for distillation of product)

**PRODUCT(S):** Bromoalkane

**REACTION TYPE:** Halogenation

**REACTIONS:**  
(example of  
ethanol)



**NOTES:**

- KBr and  $\text{H}_2\text{SO}_4$  react together to form HBr that reacts with the alcohol to form the bromoalkane.
- Bromoalkane is isolated from the reaction mixture by distillation.





# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

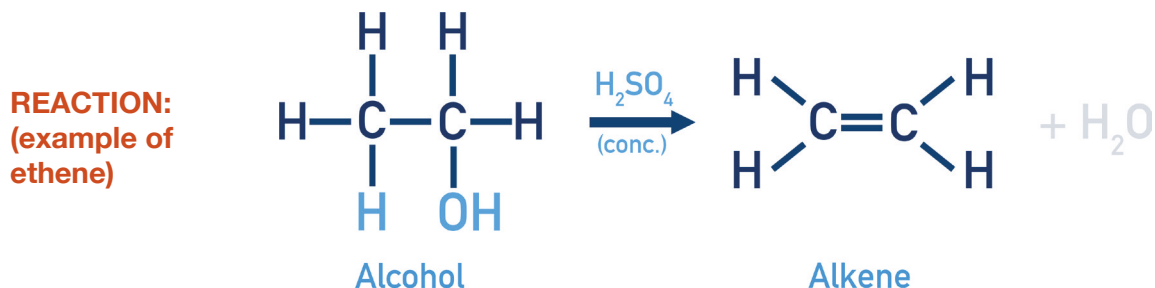
### Alcohols Elimination (to alkenes)

**REACTANTS:** Alcohol

**CONDITIONS:** Heat, Acid Catalyst (concentrated  $\text{H}_2\text{SO}_4$  or concentrated  $\text{H}_3\text{PO}_4$ )

**PRODUCT(S):** Alkene

**REACTION TYPE:** Elimination, *dehydration*



**NOTES:**

- Acid catalyst provides  $\text{H}^+$  ion to start reaction and is reformed at the end when a  $\text{H}^+$  ion is released by reacting molecule.
- Water molecule is removed, **dehydration reaction**.



# Organic Chemistry Revision Sheets

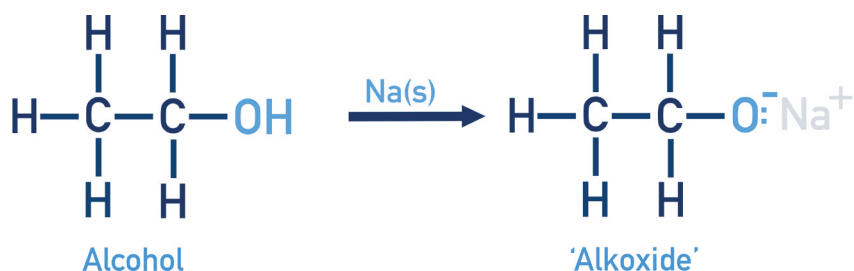
## Reactions for CIE A-Level Chemistry

### Alcohols With Sodium, Na

**REACTANTS:** Alcohol and Sodium

**PRODUCT(S):** Alkoxide and Sodium Ion ( $\text{Na}^+$ )

**REACTION:**  
(example of  
ethanol)



#### NOTES:

- Alcohol reacts in a similar way with sodium metal as water. Hydrogen gas is released, the sodium metal becomes a positively charged ion ( $\text{Na}^+$ ) and the ROH group becomes a negatively charged 'alkoxide' ion ( $\text{RO}^-$ ).
- Ethanol reacts with sodium metal to form sodium ethoxide:





# Organic Chemistry Revision Sheets

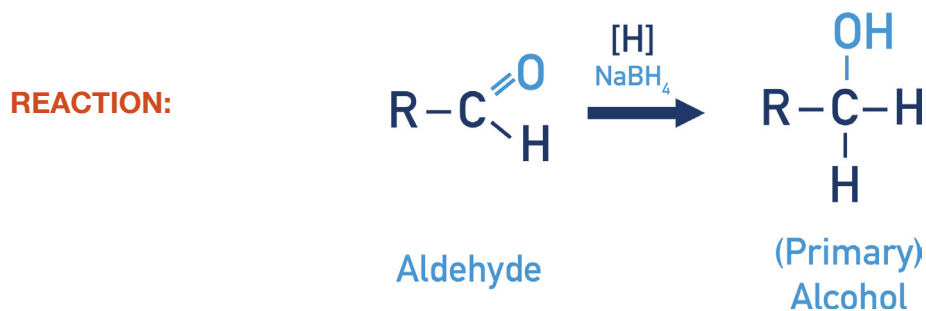
## Reactions for CIE A-Level Chemistry

### Aldehydes Reduction ( $\text{NaBH}_4$ )

**REACTANTS:** Aldehyde and  $\text{NaBH}_4$  (reducing agent)

**PRODUCT(S):** Primary Alcohol

**REACTION TYPE:** Reduction



**NOTES:**

- Aldehydes form **primary alcohols** when reduced.
- $\text{NaBH}_4$  is a reducing agent able to provide hydride ( $\text{:H}^-$ ) ions that are needed for the reduction of carbonyls.
- The hydrogens added in reduction reactions are often shown as  $[\text{H}]$ .



# Organic Chemistry Revision Sheets

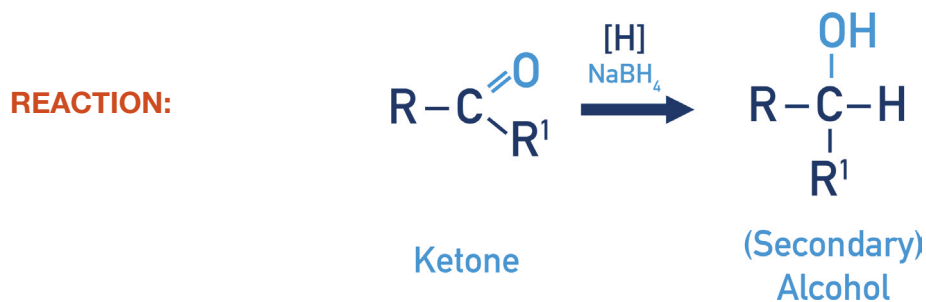
## Reactions for CIE A-Level Chemistry

### Ketones Reduction ( $\text{NaBH}_4$ )

**REACTANTS:** Ketone and  $\text{NaBH}_4$  (reducing agent)

**PRODUCT(S):** Secondary Alcohol

**REACTION TYPE:** Reduction



**NOTES:**

- Ketones form **secondary alcohols** when reduced.
- $\text{NaBH}_4$  is a reducing agent able to provide hydride ( $\text{:H}^-$ ) ions that are needed for the reduction of carbonyls.
- The hydrogens added in reduction reactions are often shown as  $[\text{H}]$ .



# Organic Chemistry Revision Sheets

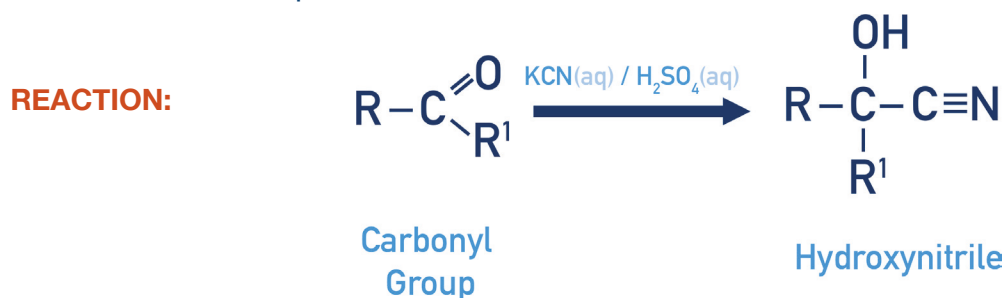
## Reactions for CIE A-Level Chemistry

### Hydroxynitriles Formation (from carbonyls)

**REACTANTS:** Carbonyl (aldehyde or ketone) and KCN (in acid)

**PRODUCT(S):** Hydroxynitrile

**REACTION TYPE:** Nucleophilic Addition



**NOTES:**

- HCN is sometimes written as the reactant, but HCN is very reactive and dangerous. By using KCN in dilute acid, the same product can be formed as with HCN.
- If a chiral carbon centre is formed in the product, the final product mixture will be **racemic**, containing both enantiomers in a 50:50 ratio. This is because carbonyl groups are planar and there is equal chance of the  $\text{:CN}^-$  nucleophile attacking the carbonyl group from above or below the plane - producing two possible enantiomers in equal amounts.

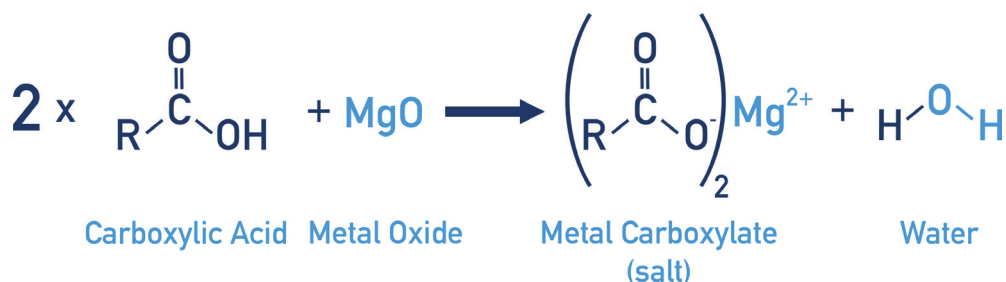
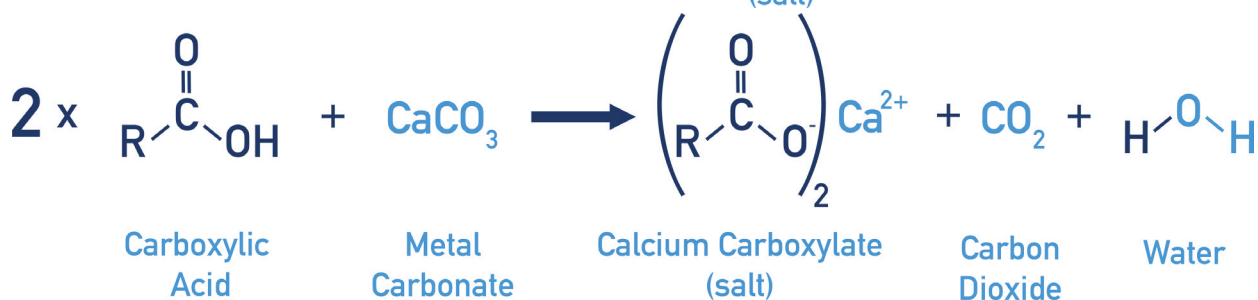
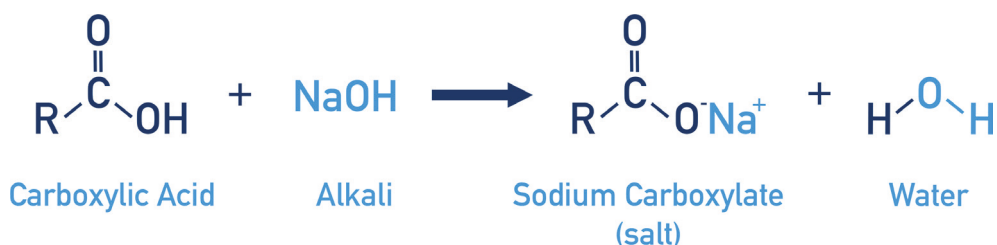
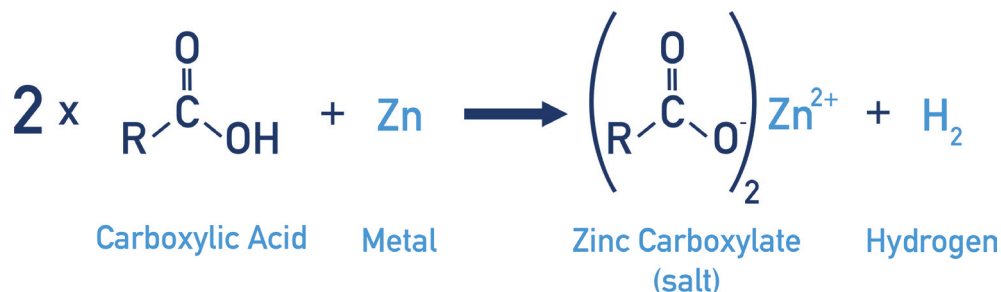


# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Carboxylic Acids Acid-Base Reactions

*Carboxylic acids are able to act as weak acids and react with bases as any weak acid does*



#### NOTES:

- Salts formed by carboxylic acids are (usually) highly soluble in water and can be a useful source of conjugate bases for making buffer systems.





# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Carboxylic Acids Reduction (to alcohols using $\text{LiAlH}_4$ )

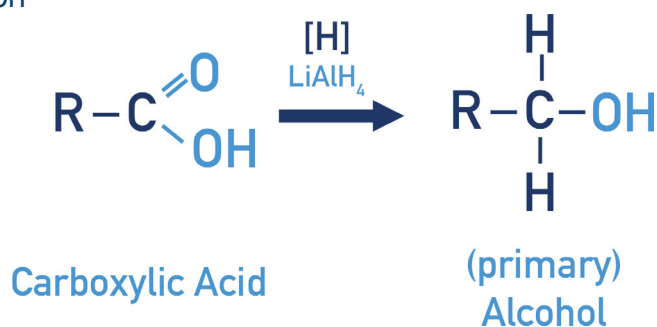
**REACTANTS:** Carboxylic Acid and  $\text{LiAlH}_4$

**CONDITIONS:** Dry ether (room temperature)

**PRODUCT(S):** Primary Alcohol

**REACTION TYPE:** Reduction

**REACTION:**



**NOTES:**

- $\text{LiAlH}_4$  is used as the reducing agent as  $\text{NaBH}_4$  isn't powerful enough to reduce the carboxylic acid.
- Reducing agent can be represented as  $[\text{H}]$  when writing the reaction:



- Reaction must be carried out in dry ether (no water present) as  $\text{LiAlH}_4$  reacts vigorously with water.





# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

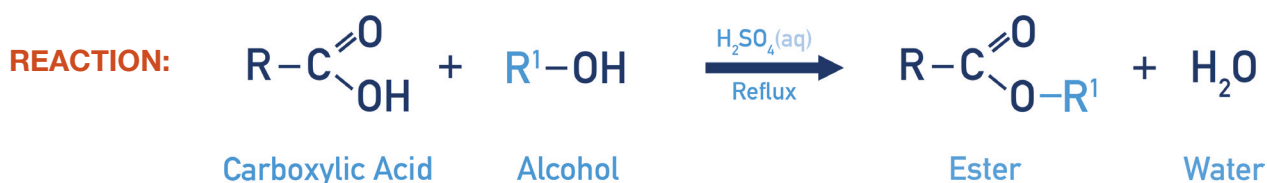
### Esters Esterification (carboxylic acid and alcohol)

**REACTANTS:** Carboxylic Acid and Alcohol

**CONDITIONS:** Heat under reflux and (concentrated) Sulfuric Acid ( $\text{H}_2\text{SO}_4$ ) catalyst

**PRODUCT(S):** Ester

**REACTION TYPE:** Condensation, *Esterification*



**NOTES:**

- Reaction is reversible (see hydrolysis of esters), so a (concentrated) acid catalyst is needed to force the position of equilibrium to the formation of ester.





# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Esters Hydrolysis

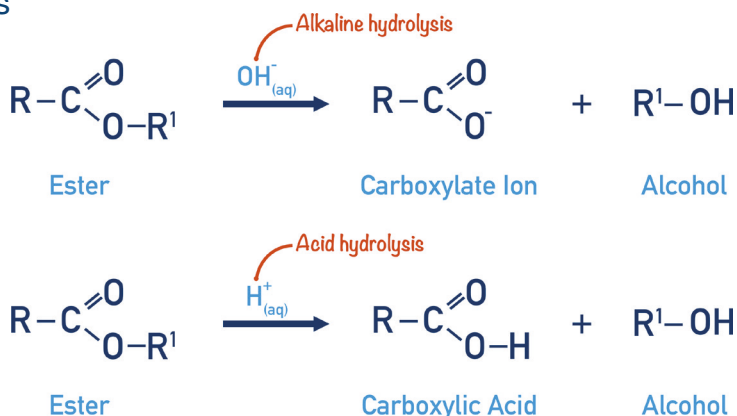
**REACTANTS:** Ester

**CONDITIONS:** Warm, Aqueous (with dilute acid or alkali)

**PRODUCT(S):** Carboxylic Acid (or carboxylate salt) and Alcohol

**REACTION TYPE:** Hydrolysis

**REACTION(S):**



**NOTES:**

- If alkaline (OH<sup>-</sup>) conditions are used, a carboxylate ion is formed and can be isolated by adding a dilute acid.
- Fats and oils are tri-esters and can be broken down into three fatty acid molecules (carboxylic acids) and one alcohol molecule (glycerol) by hydrolysis.
- Biodiesel can be made by the reaction of oil (tri-ester) with methanol in the presence of an acid catalyst, forming methyl esters that can be used as a diesel fuel.



# Organic Chemistry Revision Sheets

## Reactions for CIE A-Level Chemistry

### Nitriles Acid Hydrolysis (to form carboxylic acids)

**REACTANTS:** Nitrile and (dilute) Hydrochloric Acid (HCl)

**CONDITIONS:** Heat under reflux

**PRODUCT(S):** Carboxylic Acid and Ammonium Chloride

**REACTION TYPE:** Hydrolysis



**NOTES:**

- Full reaction:



- Nitriles can also be hydrolysed in alkaline conditions (heated under reflux) using sodium hydroxide, forming the sodium carboxylate salt of the carboxylic acid.

