



Organic Chemistry Revision Sheets

Reactions for OCR (A) A-Level Chemistry

Alkanes Combustion

REACTANTS: Alkane and O₂ (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).





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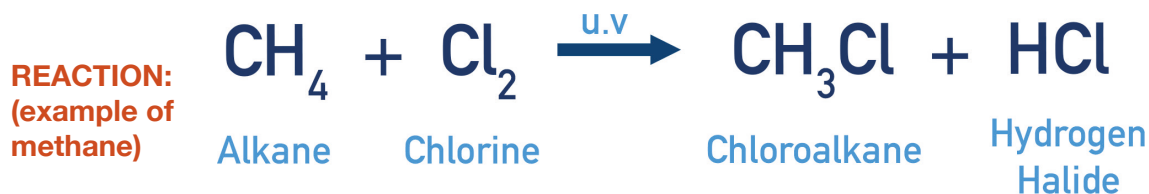
Alkanes Free Radical Substitution

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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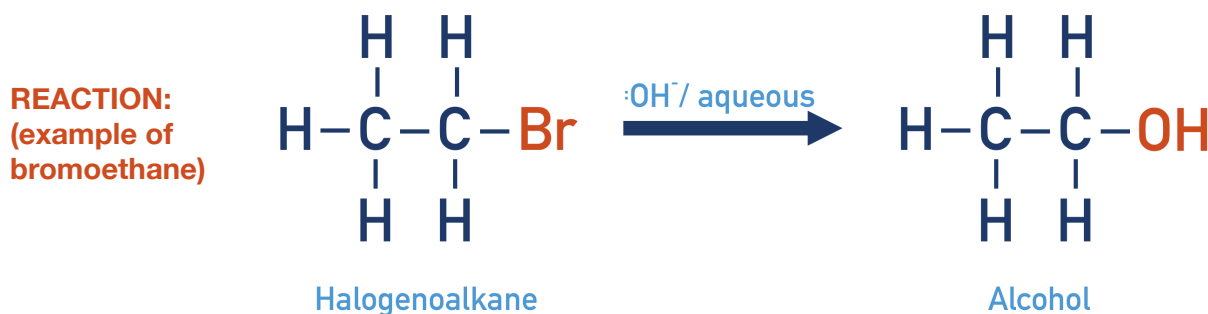
Halogenoalkanes Substitution (OH^-)

REACTANTS: Halogenoalkane and Sodium Hydroxide, NaOH (for 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 (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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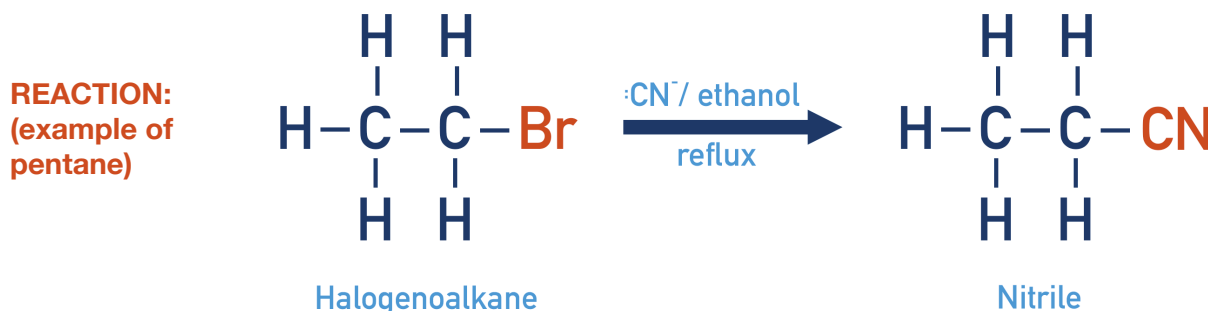
Halogenoalkanes Substitution (CN⁻)

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⁺ or K⁺*)

REACTION TYPE: Nucleophilic Substitution



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 OCR (A) A-Level Chemistry

Decomposition (Free Radical) Ozone

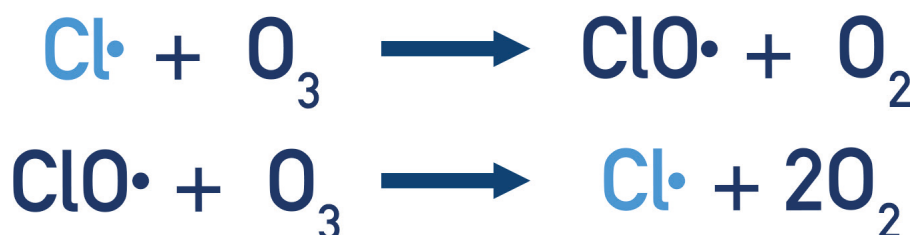
REACTANTS: Chlorine Radical and Ozone (O_3)

CONDITIONS: Upper Atmosphere, (u.v light to form chlorine radical)

PRODUCT(S): Oxygen

REACTION TYPE: Decomposition (Free Radical)

REACTION:
(example of
ozone)



NOTES:

- Chlorine radical is formed by homolytic fission of chlorine molecule in upper atmosphere by u.v light.
- This is a chain reaction as the chlorine radical is reformed and can go on to decompose more ozone molecules.
- Ozone (O_3) prevents u.v radiation from reaching the surface of planet Earth. The use of CFC's (chlorofluorinated carbons) in the 20th century lead to a depletion of ozone in the upper atmosphere; CFCs were banned as a result.





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Reactions for OCR (A) A-Level Chemistry

Alkenes Addition (HBr)

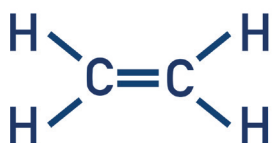
REACTANTS: Alkene and Hydrogen Bromide (HBr)

CONDITIONS: Hydrogen Bromide Gas or (concentrated) Hydrobromic Acid

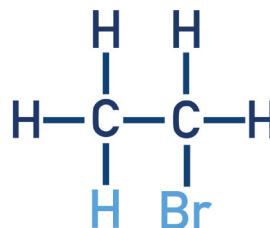
PRODUCT(S): Bromoalkane

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*.



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Reactions for OCR (A) A-Level Chemistry

Alkenes Addition (Br_2)

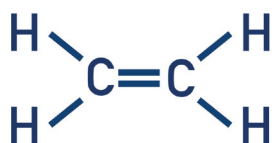
REACTANTS: Alkene and Bromine (Br_2)

CONDITIONS: Bromine Liquid (pure Br_2) or Bromine Water ($\text{Br}_2(\text{aq})$)

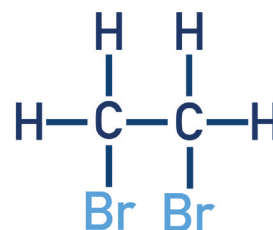
PRODUCT(S): Dibromoalkane

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.





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Reactions for OCR (A) A-Level Chemistry

Alkenes Hydration (to alcohol)

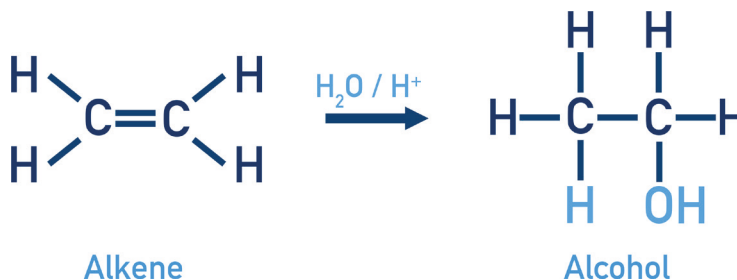
REACTANTS: Alkene and Steam ($\text{H}_2\text{O}_{(\text{g})}$)

CONDITIONS: Heat and Acid Catalyst (Phosphoric Acid, H_3PO_4)

PRODUCT(S): Alcohol

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

REACTION:
(example of
ethene)



NOTES:

- Acid catalyst is required to form hydroxonium ion (H_3O^+) 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*.



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Reactions for OCR (A) A-Level Chemistry

Alkenes Hydrogenation (to alkane)

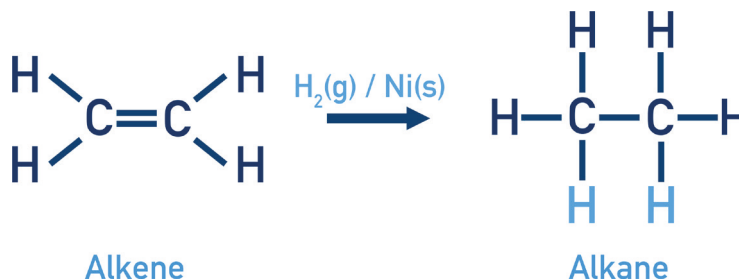
REACTANTS: Alkene and Hydrogen, H_2

CONDITIONS: Approximately $150^\circ C$ 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)).



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Reactions for OCR (A) A-Level Chemistry

Alcohols Oxidation

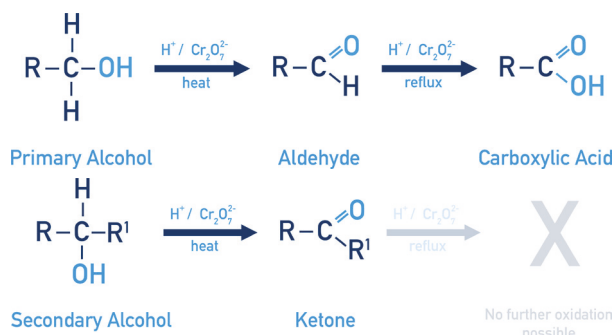
REACTANTS: Alcohol (primary or secondary) and Acidified Dichromate ions ($\text{Cr}_2\text{O}_7^{2-} / \text{H}^+$)

CONDITIONS: Heat*, Acid Catalyst (sulfuric acid (H_2SO_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].



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Reactions for OCR (A) A-Level Chemistry

Alcohols Halogenation (KBr)

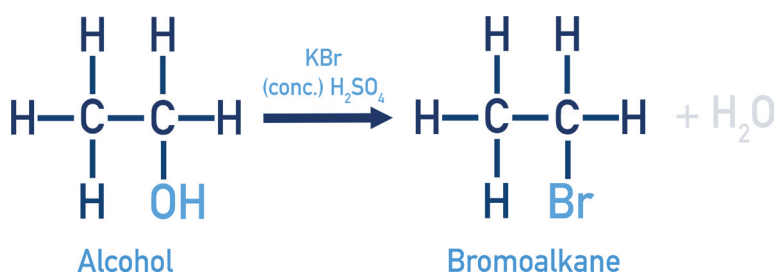
REACTANTS: Alcohol and 50% (concentrated) H_2SO_4 and Potassium Bromide, KBr

CONDITIONS: (concentrated) H_2SO_4 , Warm Temperature (for distillation of product)

PRODUCT(S): Bromoalkane

REACTION TYPE: Halogenation

REACTIONS:
(example of
ethanol)



NOTES:

- KBr and H_2SO_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 OCR (A) A-Level Chemistry

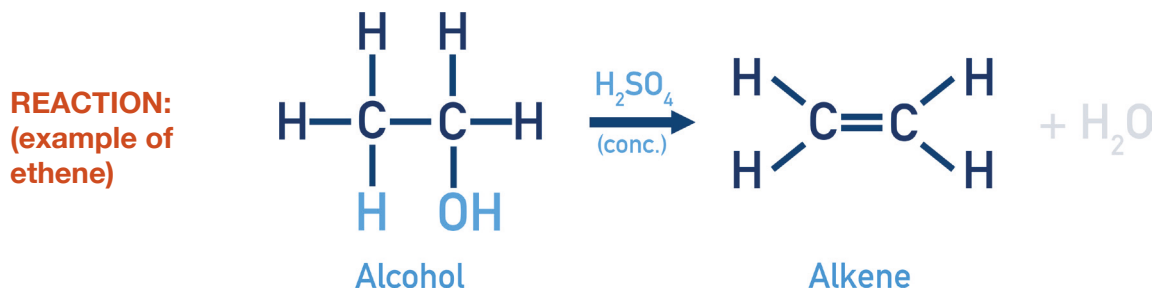
Alcohols Elimination (to alkenes)

REACTANTS: Alcohol

CONDITIONS: Heat, Acid Catalyst (concentrated H_2SO_4 or concentrated H_3PO_4)

PRODUCT(S): Alkene

REACTION TYPE: Elimination, *dehydration*



NOTES:

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



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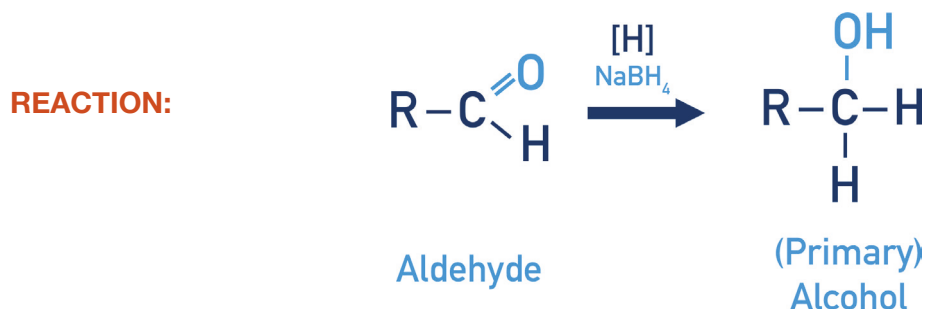
Reactions for OCR (A) A-Level Chemistry

Aldehydes Reduction (NaBH_4)

REACTANTS: Aldehyde and NaBH_4 (reducing agent)

PRODUCT(S): Primary Alcohol

REACTION TYPE: Reduction



NOTES:

- Aldehydes form **primary alcohols** when reduced.
- NaBH_4 is a reducing agent able to provide hydride (:H^-) ions that are needed for the reduction of carbonyls.
- The hydrogens added in reduction reactions are often shown as $[\text{H}]$.



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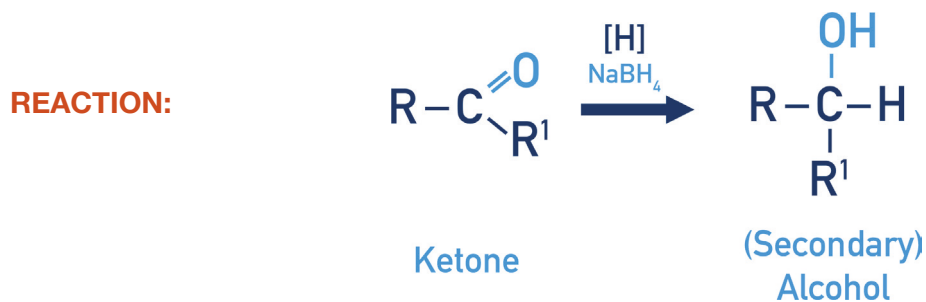
Reactions for OCR (A) A-Level Chemistry

Ketones Reduction (NaBH_4)

REACTANTS: Ketone and NaBH_4 (reducing agent)

PRODUCT(S): Secondary Alcohol

REACTION TYPE: Reduction



NOTES:

- Ketones form **secondary alcohols** when reduced.
- NaBH_4 is a reducing agent able to provide hydride (:H^-) ions that are needed for the reduction of carbonyls.
- The hydrogens added in reduction reactions are often shown as $[\text{H}]$.



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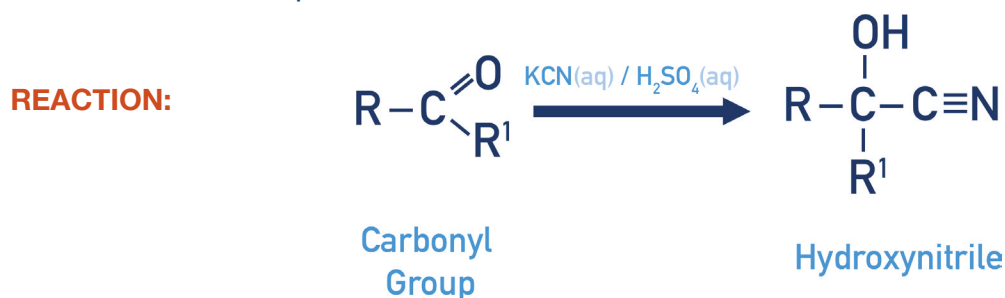
Reactions for OCR (A) A-Level Chemistry

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 :CN^- nucleophile attacking the carbonyl group from above or below the plane - producing two possible enantiomers in equal amounts.

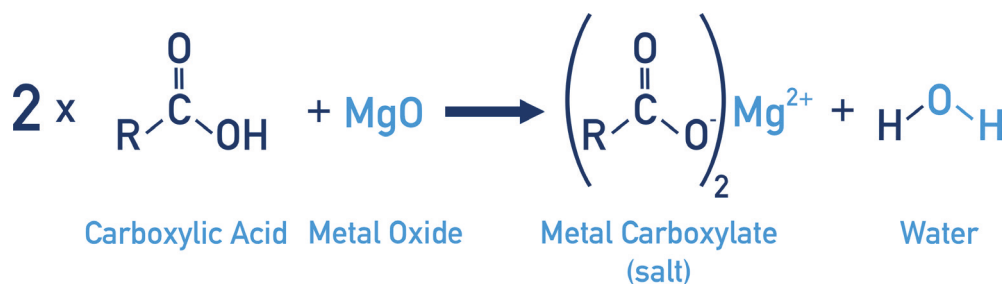
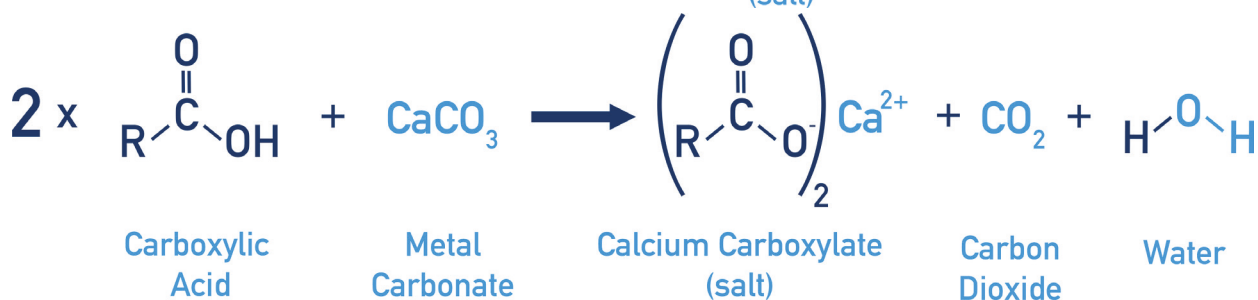
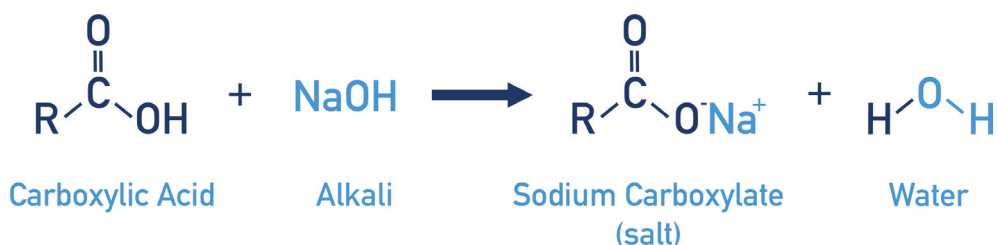
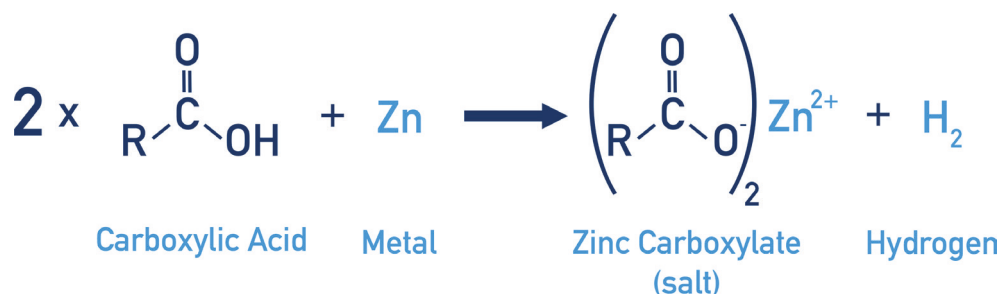


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Reactions for OCR (A) A-Level Chemistry

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.



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Reactions for OCR (A) A-Level Chemistry

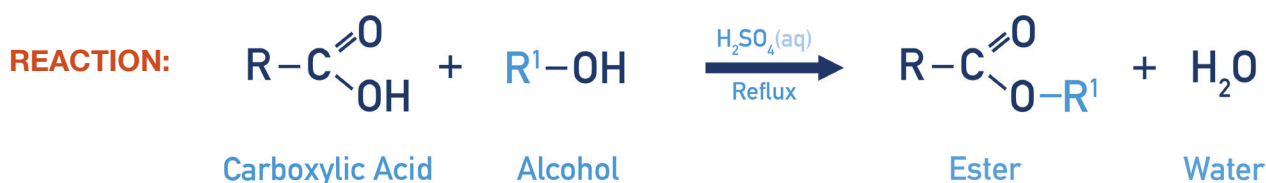
Esters Esterification (carboxylic acid and alcohol)

REACTANTS: Carboxylic Acid and Alcohol

CONDITIONS: Heat under reflux and (concentrated) Sulfuric Acid (H_2SO_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.



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Reactions for OCR (A) A-Level Chemistry

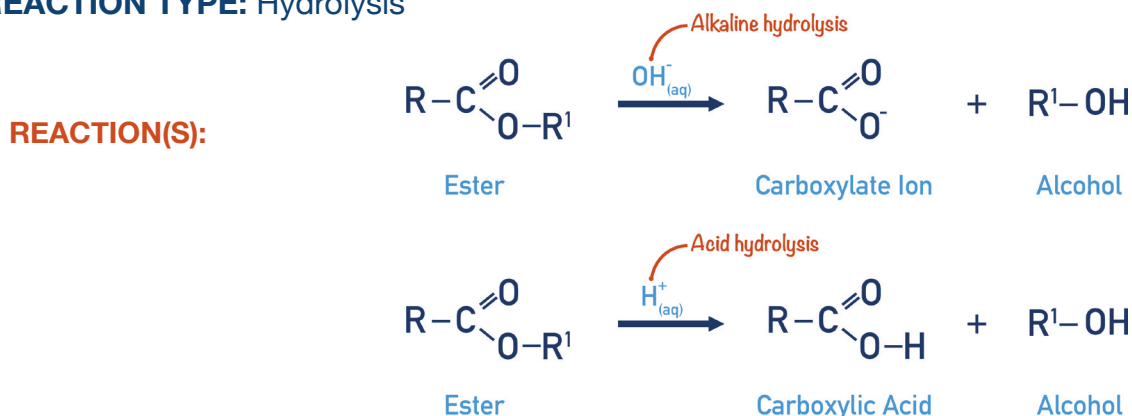
Esters Hydrolysis

REACTANTS: Ester

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

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

REACTION TYPE: Hydrolysis



NOTES:

- If alkaline (OH^-) 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.



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Reactions for OCR (A) A-Level Chemistry

Acyl Chlorides Formation (using SOCl_2)

REACTANTS: Carboxylic Acid and Sulfur Dichloride Oxide (SOCl_2)

PRODUCT(S): neat SOCl_2 (pure liquid SOCl_2)



NOTES:

- Sulfur dioxide and hydrogen chloride gas are released as products.





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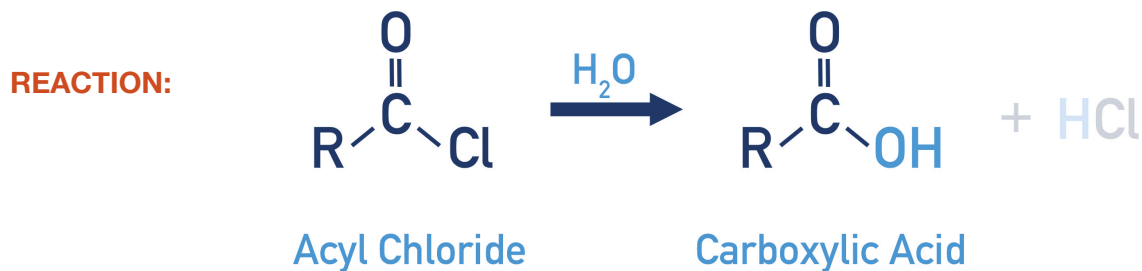
Reactions for OCR (A) A-Level Chemistry

Acyl Chlorides Addition-Elimination (H_2O)

REACTANTS: Acyl Chloride and H_2O

PRODUCT(S): Carboxylic Acid and HCl

REACTION TYPE: Nucleophilic Addition-Elimination, *Hydrolysis of acyl chloride*



NOTES:

- Acyl chlorides are highly reactive and the reaction is vigorous, with heat given off (exothermic) and fumes of HCl released.



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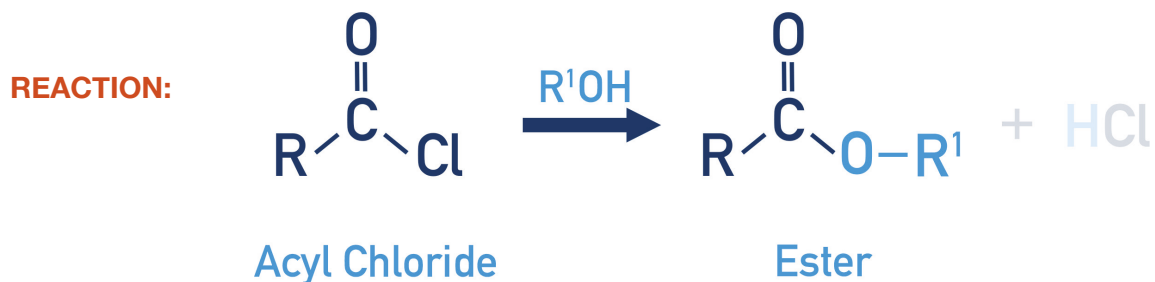
Reactions for OCR (A) A-Level Chemistry

Acyl Chlorides Addition-Elimination (alcohol)

REACTANTS: Acyl Chloride and Alcohol

PRODUCT(S): Ester and HCl

REACTION TYPE: Nucleophilic Addition-Elimination, *Esterification*



NOTES:

- Ester formed (esterification) has a sweet, fruity smell.



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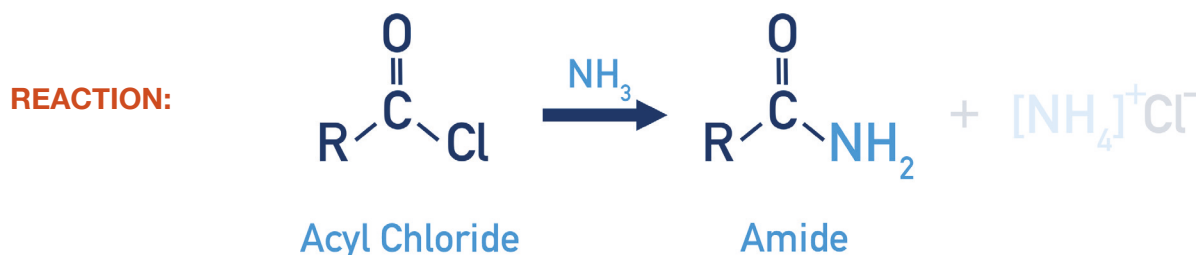
Reactions for OCR (A) A-Level Chemistry

Acyl Chlorides Addition-Elimination (NH_3)

REACTANTS: Acyl Chloride and Ammonia

PRODUCT(S): Amide and HCl

REACTION TYPE: Nucleophilic Addition-Elimination



NOTES:

- Ammonia produces a **primary amide** and ammonium chloride salt when reacted with acyl chlorides.
- Primary amines produce a **secondary amide** and an alkyl ammonium chloride salt when reacted with acyl chlorides.
- Secondary amines produce a **tertiary amide** and an alkyl ammonium chloride salt when reacted with acyl chlorides.



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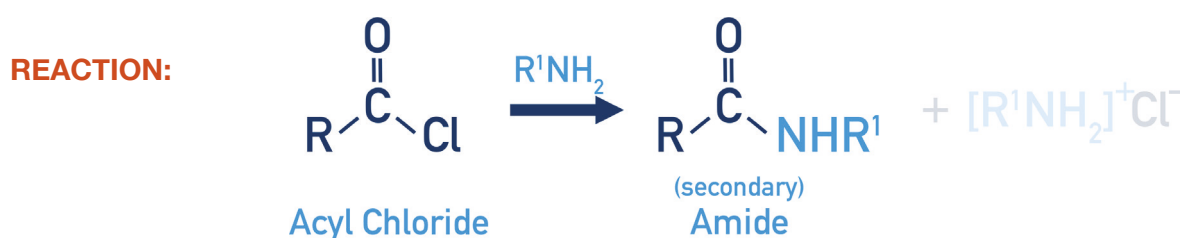
Reactions for OCR (A) A-Level Chemistry

Acyl Chlorides Addition-Elimination (amine)

REACTANTS: Acyl Chloride and Amine (primary)

PRODUCT(S): (Secondary) Amide and Alkyl Ammonium Chloride

REACTION TYPE: Nucleophilic Addition-Elimination



NOTES:

- Primary amines produce a **secondary amide** and an alkyl ammonium chloride salt when reacted with acyl chlorides.
- Secondary amines produce a **tertiary amide** and an alkyl ammonium chloride salt when reacted with acyl chlorides.



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Reactions for Edexcel A-Level Chemistry

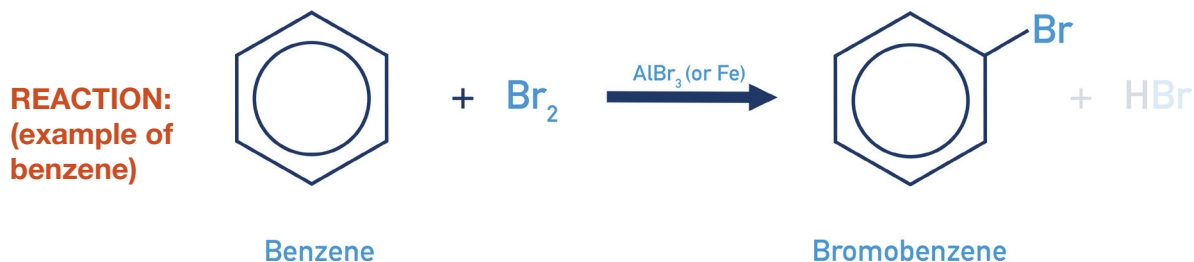
Benzene Bromination (adding Br₂)

REACTANTS: Benzene and Bromine (Br₂)

CONDITIONS: Halogen Carrier (AlBr₃ or Fe)

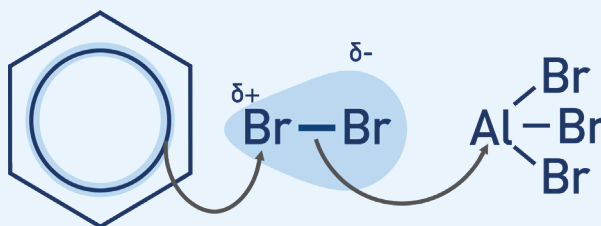
PRODUCT(S): Bromobenzene

REACTION TYPE: Electrophilic Substitution, *Bromination*



NOTES:

- The delocalised electron system in benzene is unable to polarise the bromine molecule enough to form an electrophile.
- A halogen carrier (AlBr₃ or Fe) is used to form the bromine electrophile.



- H⁺ ion removed from benzene ring combines with Br from halogen carrier intermediate, [AlBr₄]⁻ to form HBr and reform the halogen carrier (AlBr₃)





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Reactions for OCR (A) A-Level Chemistry

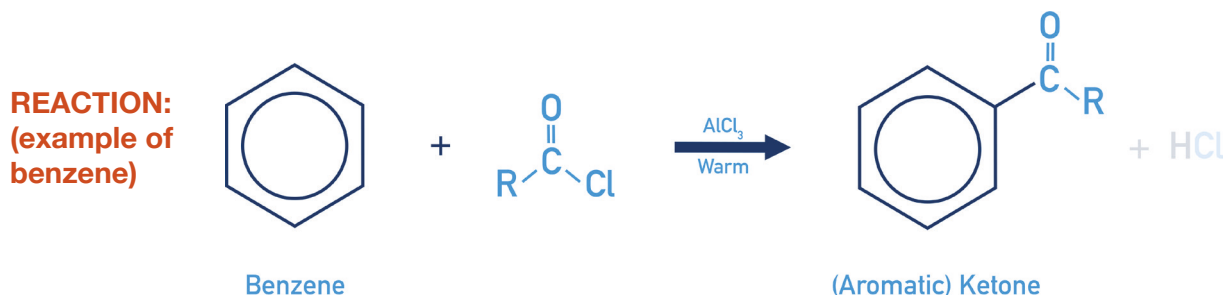
Benzene Acylation (with acyl chlorides)

REACTANTS: Benzene and Acyl Chloride

CONDITIONS: Warm and AlCl_3 catalyst

PRODUCT(S): (Aromatic) Ketone

REACTION TYPE: Electrophilic Substitution, *Acylation (Friedel Crafts)*



NOTES:

- Acylium (RCO^+) ion is formed by reacting an acyl chloride with a halogen carrier (AlCl_3).



- H^+ ion removed from benzene ring combines with $[\text{AlCl}_4]^-$ to reform AlCl_3 catalyst and form HCl .





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Reactions for OCR (A) A-Level Chemistry

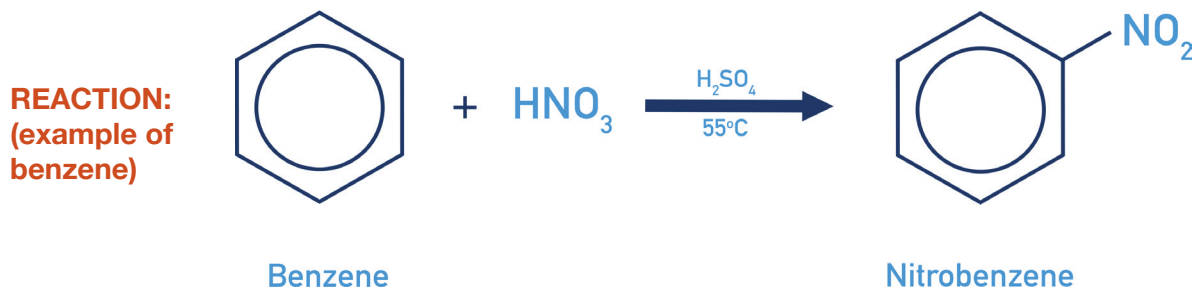
Benzene Nitration (adding NO_2)

REACTANTS: Benzene and (concentrated) Nitric Acid (HNO_3)

CONDITIONS: (Concentrated) Sulfuric Acid (H_2SO_4)

PRODUCT(S): Nitrobenzene

REACTION TYPE: Electrophilic Substitution, *Nitration*



NOTES:

- Nitronium ion is formed by the reaction of concentrated nitric acid with concentrated sulfuric acid.



Nitronium Ion

- H^+ ion removed from benzene ring combines with hydrogen sulfate (HSO_4^-) ion to reform catalyst H_2SO_4 .





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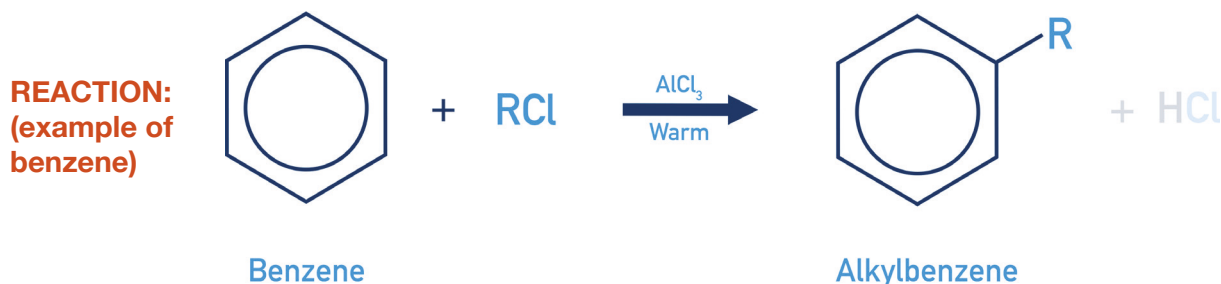
Benzene Alkylation (with halogenoalkanes)

REACTANTS: Benzene and Halogenoalkane

CONDITIONS: Warm and AlCl_3 (or AlBr_3) catalyst

PRODUCT(S): Alkylbenzene

REACTION TYPE: Electrophilic Substitution, *Alkylation (Friedel-Crafts)*

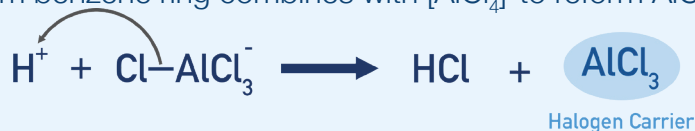


NOTES:

- Alkyl (R^+) ion is formed by reacting an acyl chloride with a halogen carrier (AlCl_3).



- H^+ ion removed from benzene ring combines with $[\text{AlCl}_4]^-$ to reform AlCl_3 catalyst and form HCl .





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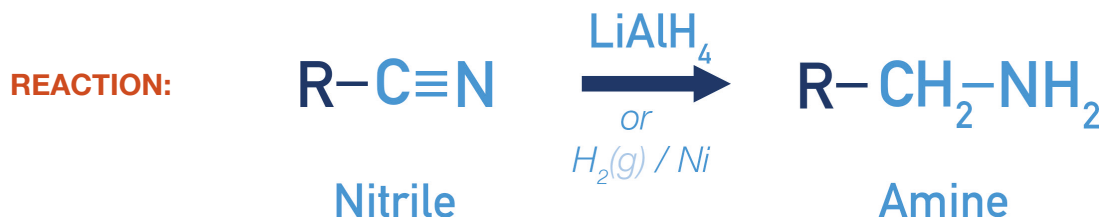
Nitriles Reduction (to form primary amine)

REACTANTS: Nitrile and Reducing Agent - LiAlH_4 , or Hydrogen gas ($\text{H}_2(\text{g})$)

CONDITIONS: Dry ether* (if using LiAlH_4), Nickel catalyst (if using $\text{H}_2(\text{g})$)

PRODUCT(S): Amine

REACTION TYPE: Reduction, Hydrogenation



NOTES:

- If $\text{H}_2(\text{g})$ and a nickel catalyst is used, the reaction is an example of catalytic hydrogenation.
- *Dry ether must be used with LiAlH_4 (LiAlH_4 reacts violently with water). To obtain the amine as a final product, dilute acid must be added to the initial product from reduction.



Organic Chemistry Revision Sheets

Reactions for OCR (A) 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.



Organic Chemistry Revision Sheets

Reactions for OCR (A) A-Level Chemistry

Nitroarenes Reduction (to form aromatic amines)

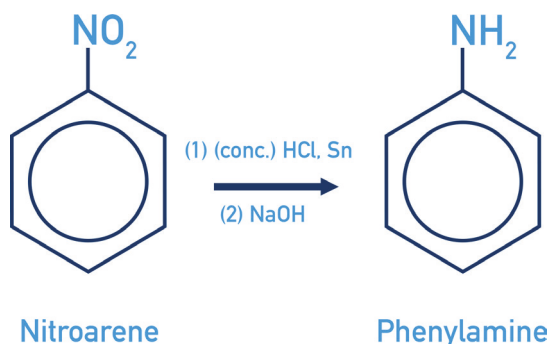
REACTANTS: Nitroarene and (concentrated) Hydrochloric Acid (HCl), *followed by NaOH*

CONDITIONS: Tin catalyst

PRODUCT(S): Aromatic Amine

REACTION TYPE: Reduction

REACTION:
(example of
nitrobenzene)



NOTES:

- When reacted with concentrated HCl, the nitroarene will form an ammonium ion -NH_3^+ . The aromatic amine can be obtained by adding dilute sodium hydroxide (to form -NH_2).



Organic Chemistry Revision Sheets

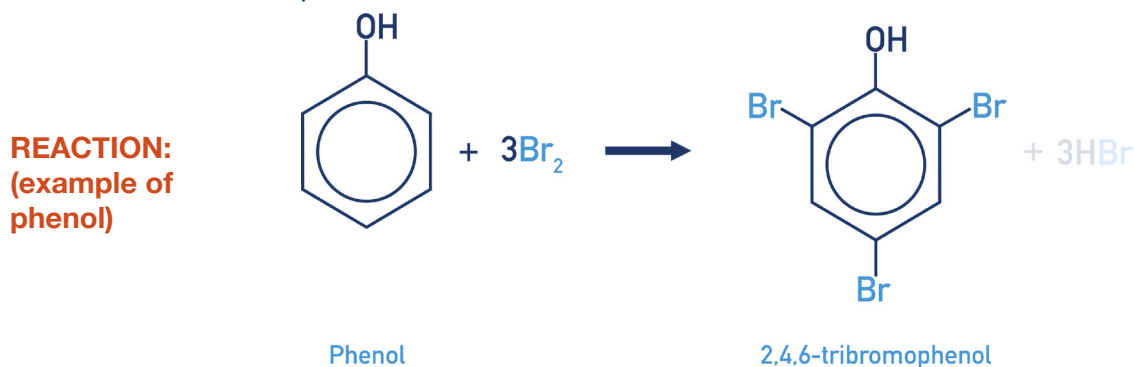
Reactions for OCR (A) A-Level Chemistry

Phenol Bromination (Br_2)

REACTANTS: Phenol and Bromine water ($\text{Br}_2(\text{aq})$)

PRODUCT(S): 2,4,6-tribromophenol

REACTION TYPE: Electrophilic Substitution, *Bromination*



NOTES:

- Bromine water changes from orange-brown to colourless and a white precipitate forms.
- Unlike with benzene, no halogen carrier catalyst is needed for the bromination of phenol. This is due to the increased electron density in the delocalised electron ring (from the $-\text{OH}$ group), making phenol more reactive than benzene.



Organic Chemistry Revision Sheets

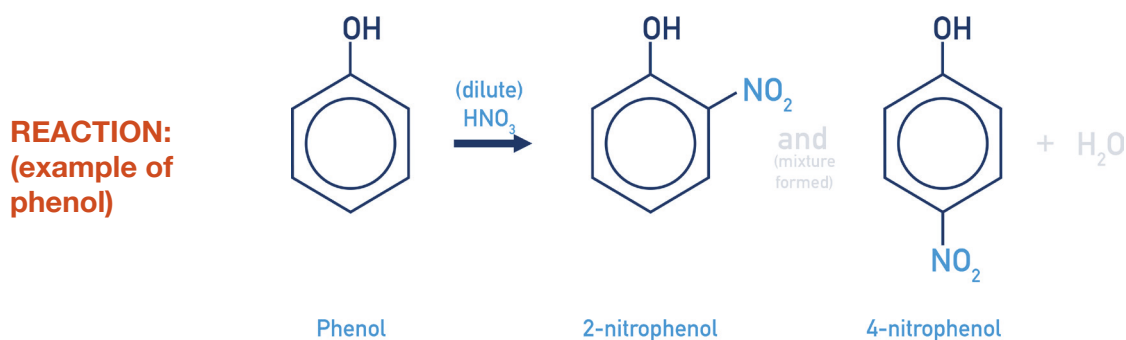
Reactions for OCR (A) A-Level Chemistry

Phenol Nitration (using dilute nitric acid, HNO_3)

REACTANTS: Phenol and dilute Nitric Acid (HNO_3)

PRODUCT(S): 2-nitrophenol and 4-nitrophenol (mixture)

REACTION TYPE: Electrophilic Substitution, *Nitration*



NOTES:

- Unlike with benzene, no sulfuric acid (H_2SO_4) catalyst is needed for the bromination of phenol. This is due to the increased electron density in the delocalised electron ring (from the -OH group) making phenol more reactive than benzene.
- If concentrated nitric acid is used, three NO_2 groups can be substituted, forming 2,4,6-trinitrophenol.



Organic Chemistry Revision Sheets

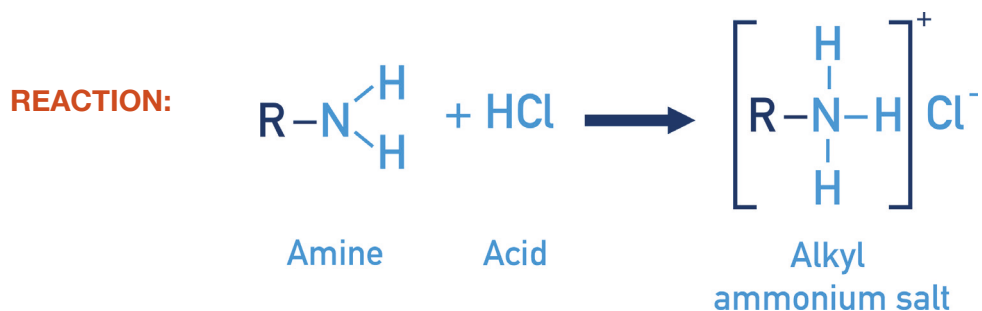
Reactions for OCR (A) A-Level Chemistry

Amines Acting as Bases (with acids)

REACTANTS: Amine and Acid

PRODUCT(S): Alkyl Ammonium Salt

REACTION TYPE: Acid-Base



NOTES:

- Nitrogen atom in amine has lone pair of electrons that can act as a base and accept a H^+ ion in an acidic solution, forming an alkyl ammonium salt (with the negative ion from the acid).
- Butylamine with hydrochloric acid:





Organic Chemistry Revision Sheets

Reactions for Edexcel A-Level Chemistry

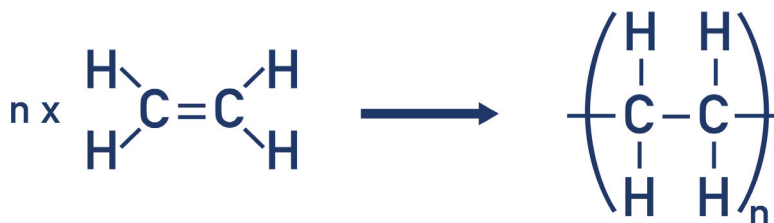
Polymers Addition (from alkenes)

REACTANTS: Alkene

PRODUCT(S): Poly(alkene)

REACTION TYPE: Addition Polymerisation

REACTION:
(example of
ethene)



Ethene

Polyethene

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**.



Monomer

Repeating Unit

Polymer





Organic Chemistry Revision Sheets

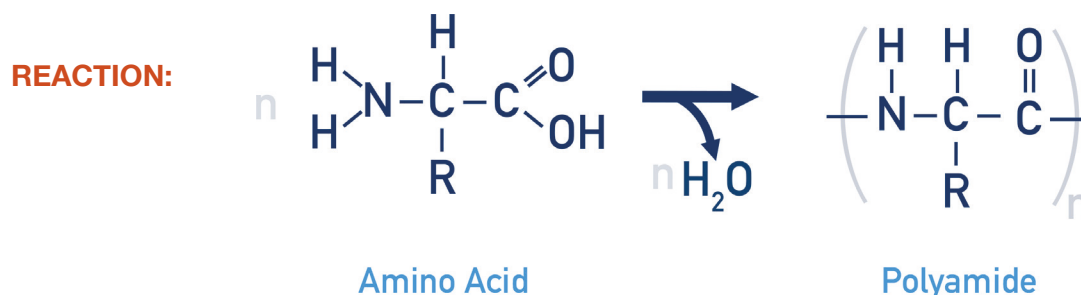
Reactions for OCR (A) A-Level Chemistry

Amino Acids Condensation Polymerisation (form proteins)

REACTANTS: Amino Acids

PRODUCT(S): Polyamide (polypeptide)

REACTION TYPE: Condensation Polymerisation



NOTES:

- Polymer formed is a polyamide, often referred to as a polypeptide in biology.
- Polyamide chains formed by amino acids are used in nature to make up proteins.
- DNA is a 'code' used by organisms to give the correct amino acid sequence for a particular protein. A section of DNA that codes for a given protein is called a gene.