CIE Chemistry A-Level

Topic 15 - Hydrocarbons

Flashcards

Why are alkanes generally unreactive?

Why are alkanes generally unreactive?

- C-C and C-H bonds have a fairly high bond enthalpy and therefore require a lot of energy to overcome.
- The difference in electronegativities of C and H is so small, making it very resistant to reactions with polar reagents.

Write the chemical equation for the complete combustion of ethane

Write the chemical equation for the complete combustion of ethane

$$C_2H_6 + 3\frac{1}{2}O_2 \rightarrow 2CO_2 + 3H_2O$$

Write an overall equation for the substitution reaction of ethane with chlorine. Include any conditions.

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UV light

$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$

What are the three steps of free radical substitution?

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1. Initiation
2. Propagation
3. Termination

Write the mechanism for the free radical substitution of ethane with chlorine

Write the mechanism for the free radical substitution of ethane with chlorine

Initiation: $Cl_2 \rightarrow 2Cl\bullet$

Propagation: $C_2H_6 + \bullet Cl \rightarrow \bullet C_2H_5 + HCl$

$\bullet C_2H_5 + Cl_2 \rightarrow C_2H_5Cl + \bullet Cl$

Termination: $\bullet Cl + \bullet Cl \rightarrow Cl_2$

$\bullet C_2H_5 + \bullet Cl \rightarrow C_2H_5Cl$

$\bullet C_2H_5 + \bullet C_2H_5 \rightarrow C_4H_{10}$

What is crude oil a source of?

What is crude oil a source of?

Aliphatic and aromatic alkanes

What is cracking?

What is cracking?

The process in which complex organic molecules are broken down into smaller organic molecules, such as simple alkanes.

Why is cracking used?

Why is cracking used?

To obtain more useful and smaller alkanes and alkenes

What are the conditions and reagents for the hydrogenation of alkenes. Write an equation for the hydration of ethene

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- Hydrogen gas
- Nickel catalyst
- 150°C

$C_2H_4 + H_2 \rightarrow C_2H_6$

What are the conditions and reagents for the hydration of alkenes? Write an equation for the hydration of ethene

What are the conditions and reagents for the hydration of alkenes? Write an equation for the hydration of ethene

- Steam
- H_3PO_4 catalyst
- 300°C degrees
- 60-70 atm

$C_2H_4 + H_2O \rightarrow C_2H_5OH$

What are the conditions for the reactions between alkenes and halogens? Write an equation for the reaction between ethene and bromine

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- Room temperature

$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

What are the conditions for the reactions between alkenes and hydrogen halides? Write an equation for the reaction between ethene and hydrogen bromide

What are the conditions for the reactions between alkenes and hydrogen halides? Write an equation for the reaction between ethene and hydrogen bromide

- Room temperature

$C_2H_4 + HBr \rightarrow C_2H_5Br$

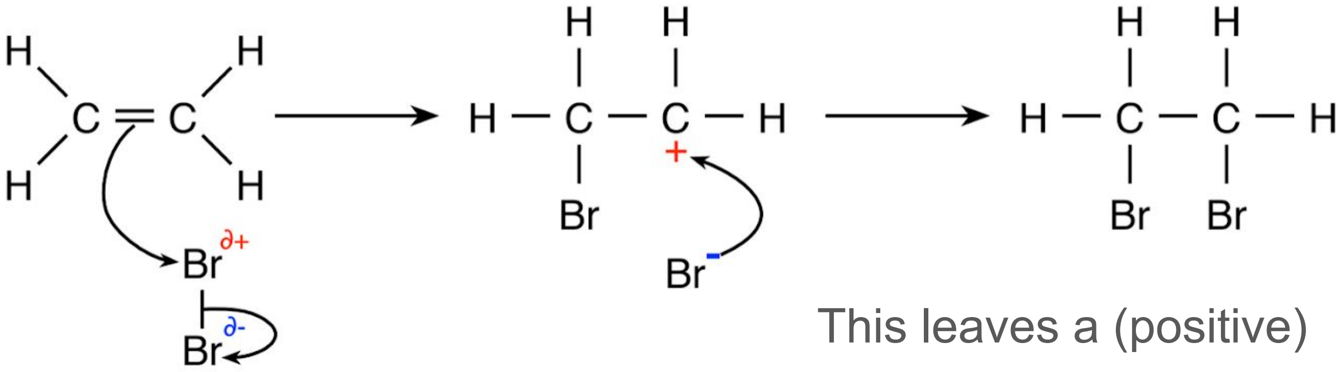
What is Markovnikov’s rule?

What is Markovnikov's rule?

In the electrophilic addition of a hydrogen halide to an asymmetric alkene, the hydrogen atom will bond to the carbon that is already bonded to the most hydrogens.

Draw the mechanism for the electrophilic addition reaction between ethene and bromine

Draw the mechanism for the electrophilic addition reaction between ethene and bromine



The electron dense carbon-carbon double bond induces a dipole in the Br_2 molecule. The π bond breaks and a carbon atom forms a bond with a bromine atom.

This leaves a (positive) carbocation that is attracted to the negative bromide ion and hence forms a covalent bond with it.

Draw the mechanism for the electrophilic addition reaction between propene and hydrogen bromide (forming the minor product)

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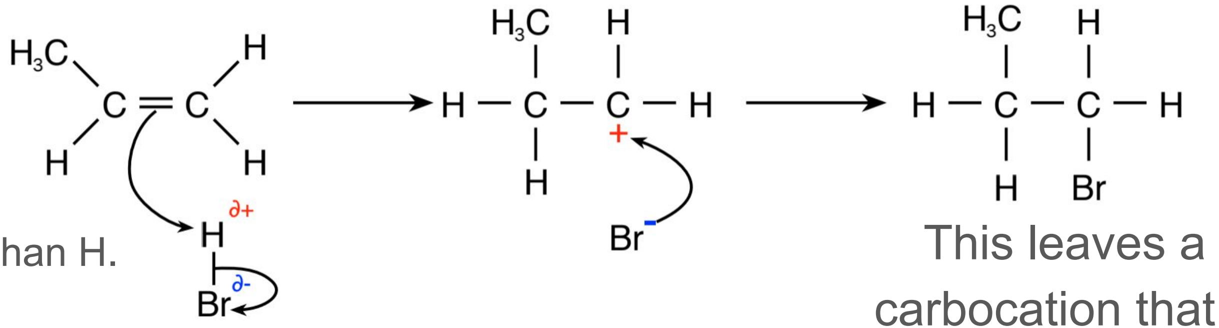


Br is more electronegative than H.

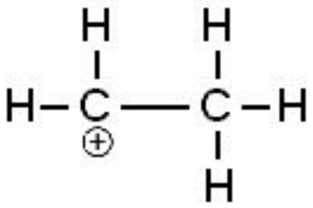
The electron dense C=C double bond is attracted to the slightly positive hydrogen, causing the π bond to break and a covalent bond to form between the carbon and hydrogen atom.

This leaves a (positive) carbocation that is attracted to the negative bromide ion and hence forms a covalent bond with it.

How are carbocations classified?

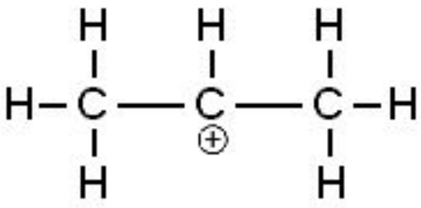
How are carbocations classified?

Primary



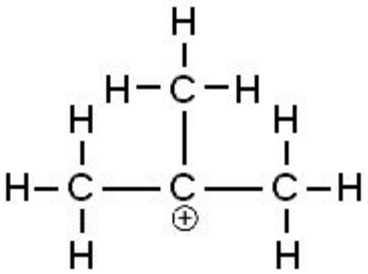
Carbocation is bonded to one alkyl group.

Secondary



Carbocation is bonded to two alkyl groups.

Tertiary



Carbocation is bonded to three alkyl groups.

What is the trend in carbocation stability?

What is the trend in carbocation stability?

Primary → Secondary → Tertiary

Stability increases →

The more alkyl groups attached to the carbocation, the more the positive charge is spread out, increasing stability.

In terms of carbocation stability, what will be the major product in the addition reaction between a hydrogen halide and an unsymmetrical alkene?

In terms of carbocation stability, what will be the major product in the addition reaction between a hydrogen halide and an unsymmetrical alkene?

The major product will be the one whose carbocation intermediate has the greater stability i.e. a secondary carbocation is more likely to form than a primary carbocation.

How can alkenes be oxidised to form a diol? Write an equation for the oxidation of ethene

How can alkenes be oxidised to form a diol? Write an equation for the oxidation of ethene

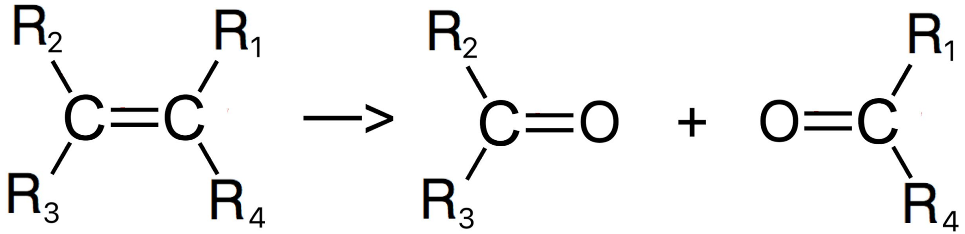
- Manganate(VII) ions are a strong oxidising agent.
- When cold, dilute and acidified, the ions experience a colour change from purple to colourless as they are reduced.

$C_2H_4 + H_2O + [O] \rightarrow (CH_2OH)_2$

What happens when an alkene is oxidised with hot, concentrated acidified potassium manganate solution?

What happens when an alkene is oxidised with hot, concentrated acidified potassium manganate solution?

The C=C double bond is broken and replaced with 2 x C=O bonds (forming 2 carbonyl compounds):

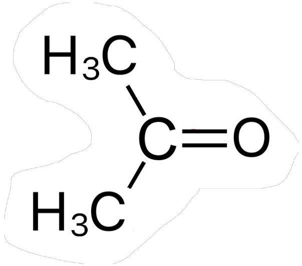


What occurs next is based on whether the R groups are alkyl groups or hydrogen atoms

After an alkene has been oxidised using hot, concentrated $H^+/Cr_2O_7^{2-}$, both R groups of one of the products are alkyl groups. What happens to this product?

After an alkene has been oxidised using hot, concentrated $H^+/Cr_2O_7^{2-}$, both R groups of one of the products are alkyl groups. What happens to this product?

- The alkene was split into a ketone (where both R groups are alkyl groups) and another carbonyl
- Ketones cannot be oxidised further so no further reaction occurs.



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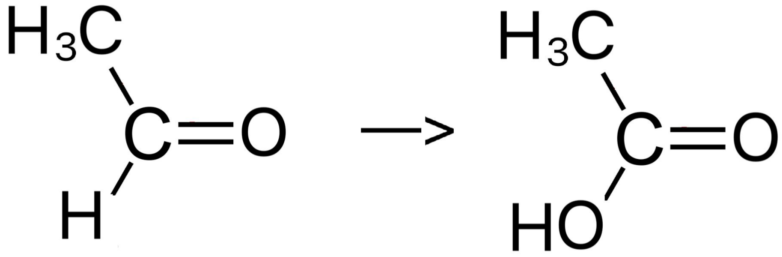
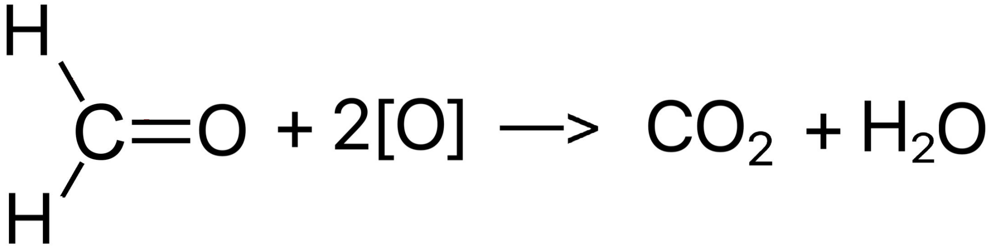
- The alkene was split into an aldehyde (with an alkyl group and a hydrogen atom as the R groups) and another carbonyl
- The aldehyde is further oxidised to form a carboxylic acid:



After an alkene has been oxidised using hot, concentrated $H^+/Cr_2O_7^{2-}$, both R groups of one of the products are hydrogen atoms. What happens to this product?

After an alkene has been oxidised using hot, concentrated $H^+/Cr_2O_7^{2-}$, both R groups of one of the products are hydrogen atoms. What happens to this product?

- The alkene was oxidised to form methanal (with 2 hydrogen atoms as R groups) and another carbonyl
- Methanal will be completely oxidised to form carbon dioxide and water:



What is addition polymerisation?

What is addition polymerisation?

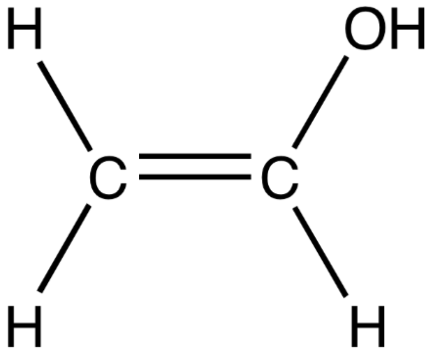
The joining together of unsaturated alkene monomers to form a polymer. No other products are formed (atom economy is 100%).

How do alkenes undergo addition polymerisation?

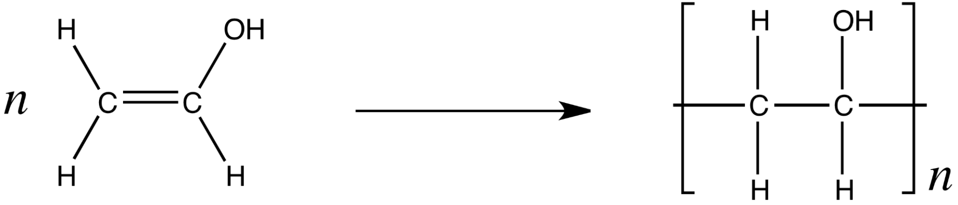
How do alkenes undergo addition polymerisation?

The π bond breaks and each electron goes towards forming a σ bond with an adjacent monomer unit.

Deduce the repeat unit of the addition polymer formed from the monomer below

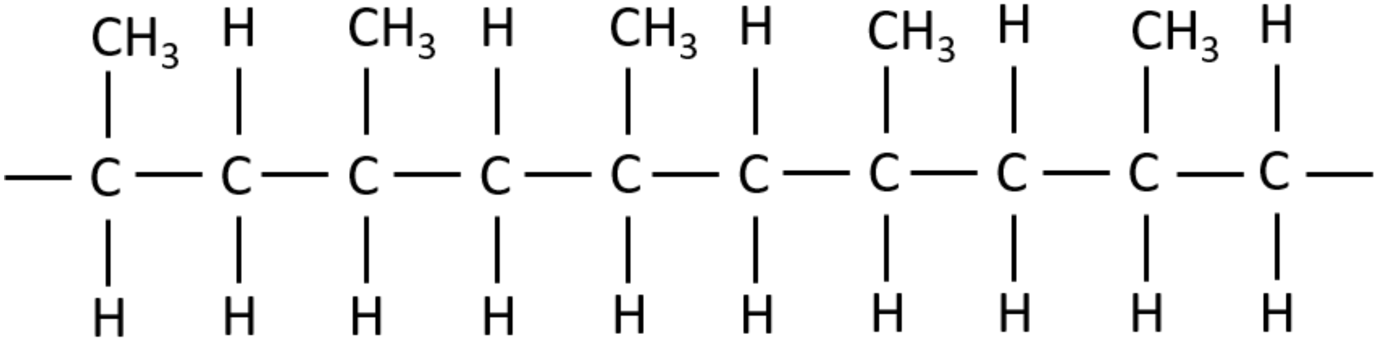


Deduce the repeat unit of the addition polymer formed from the monomer below

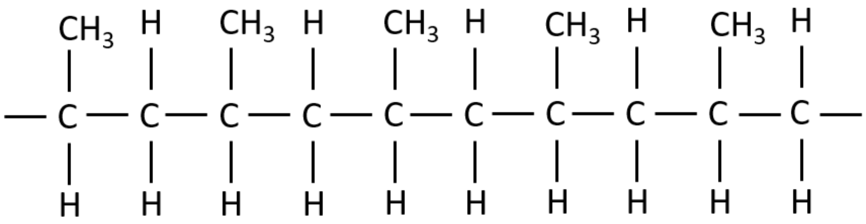


- Turn the double C=C into a single C-C.
- Add and extend bonds out from the sides of the carbon atoms.
- Add in square brackets around the molecule.

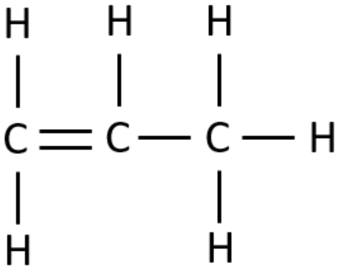
Identify the monomer that formed the addition polymer below



Identify the monomer that formed the addition polymer below



Propene



Why are polymers difficult to dispose of?

Why are polymers difficult to dispose of?

- They are non-biodegradable.
- The combustion of polymers can often form harmful compounds (such as HCl for chlorinated polymers)

Why are alkanes suitable for use as fuels?

Why are alkanes suitable for use as fuels?

High standard enthalpy changes of combustion (releases a lot of energy upon combustion)

What are the problems with carbon monoxide?

What are the problems with carbon monoxide?

- Carbon monoxide is poisonous.
- It irreversibly binds to haemoglobin, reducing the amount of oxygen that can be carried in the blood.
- Cells may become deoxygenated, leading to cell death.
- If too much CO is inhaled, this could lead to death.

Why are atmospheric oxides of nitrogen pollutants?

Why are atmospheric oxides of nitrogen pollutants?

- Nitrogen monoxide can react with chemicals that cause acid rain.
- Nitrogen dioxide can also contribute to photochemical smog.

Describe how a catalytic converter works

Describe how a catalytic converter works

- Nitrogen monoxide is formed in car engines:
  $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$
- A catalytic converter removes a majority of NO so it isn't released into the atmosphere:
  $2NO_{(g)} + 2CO_{(g)} \rightarrow N_{2(g)} + CO_{2(g)}$
- A ceramic honeycomb structure is coated in a thin layer of metal catalysts (such as platinum and rhodium)

What are the environmental consequences of unburnt hydrocarbons?

What are the environmental consequences of unburnt hydrocarbons?

Hydrocarbons in the atmosphere can absorb infrared radiation, causing the greenhouse effect.

What are the environmental consequences of the emission of greenhouse gases?

What are the environmental consequences of the emission of greenhouse gases?

Greenhouse gases cause the greenhouse effect which contributes to climate change:

- Electromagnetic radiation from the sun passes through the atmosphere. Some radiation is absorbed by Earth so temperature increases.
- Heat is radiated from the Earth as infrared radiation which is absorbed by greenhouse gases in the atmosphere. This causes the bonds in these molecules to vibrate before this energy is re-emitted.
- As a result, the atmosphere warms up even further, contributing to global warming.

How is infrared spectroscopy used to monitor air pollution?

How is infrared spectroscopy used to monitor air pollution?

- IR spectroscopy identifies particular bonds in a molecule.
- Different pollutants will have different patterns of absorption as they contain different bonds.
- It is also possible to measure the concentration of each pollutant.

Describe the halogenation of benzene

(A level only)

Describe the halogenation of benzene **(A level only)**

- E.g. Bromination:
- Benzene only reacts with bromine if a hydrogen carrier, $FeBr_3$ or $AlBr_3$, is present.
- This forms bromobenzene and hydrogen bromide: $C_6H_6 + Br_2 \rightarrow C_6H_5Br + HBr$

What is the role of the halogen carrier in the halogenation of benzene?

(A level only)

What is the role of the halogen carrier in the halogenation of benzene? **(A level only)**

- To generate the electrophile:

  $Br_2 + FeBr_3 \rightarrow FeBr_4^- + Br^+$

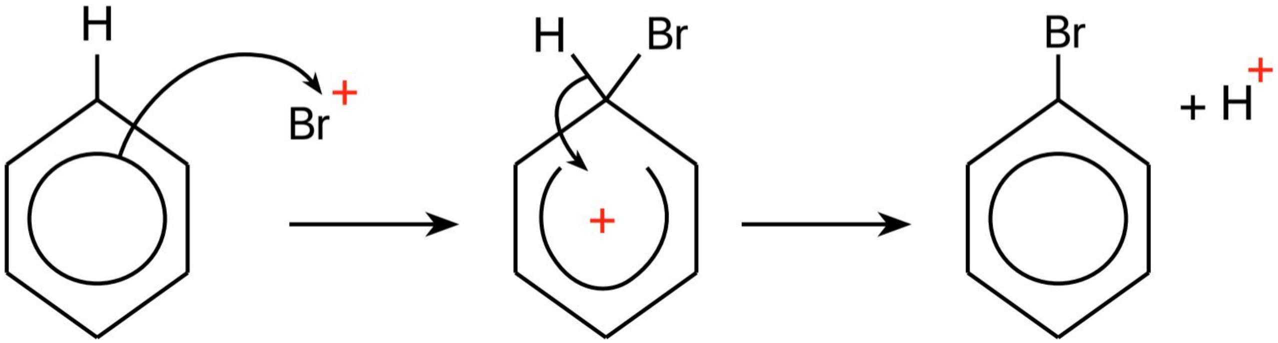
- $FeBr_4^-$ then reacts with the proton expelled from the intermediate to regenerate the halogen carrier:

  $FeBr_4^- + H^+ \rightarrow FeBr_3 + HBr$

Draw and name the mechanism for the bromination of benzene **(A level only)**

Draw and name the mechanism for the bromination of benzene **(A level only)**

Electrophilic substitution.



The Br^{+} ion accepts a pair of electrons from the ring of delocalisation.

The intermediate is so unstable that it breaks down, releasing a hydrogen ion. This forms the product, bromobenzene.

How does benzene undergo nitration?

(A level only)

How does benzene undergo nitration? **(A level only)**

Benzene reacts with conc. nitric acid at a temperature of 50°C - 60°C with a conc. sulfuric acid catalyst to from nitrobenzene and water:

$$C_6H_6 + HNO_3 \rightarrow C_6H_5NO_2 + H_2O$$

How does sulfuric acid act as a catalyst in the nitration of benzene?

(A level only)

How does sulfuric acid act as a catalyst in the nitration of benzene? **(A level only)**

- Generation of electrophile:

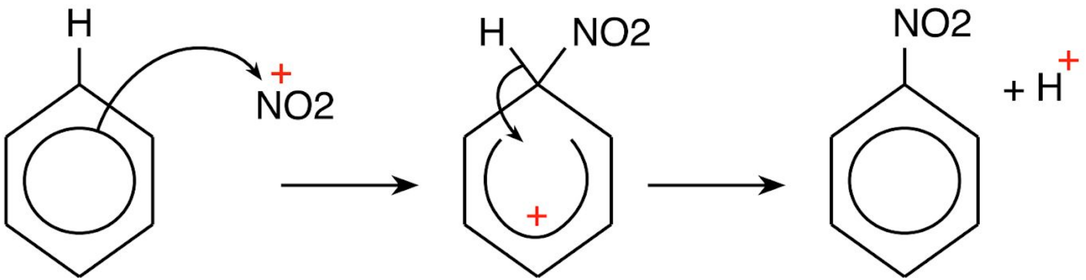
  $H_2SO_4 + HNO_3 \rightarrow NO_2^+ + HSO_4^- + H_2O$
- Sulfuric acid is regenerated when the hydrogensulfate ion reacts with the proton that is expelled from the intermediate:

  $HSO_4^- + H^+ \rightarrow H_2SO_4$

Draw and name the mechanism for the nitration of benzene **(A level only)**

Draw and name the mechanism for the nitration of benzene **(A level only)**

Electrophilic substitution



The NO^{2+} ion accepts a pair of electrons from the delocalised pi system.

The intermediate is so unstable that it breaks down, releasing a hydrogen ion. This forms the product, nitrobenzene.

How does benzene undergo an alkylation reaction? Write an equation for the reaction between benzene and chloroethane **(A level only)**

How does benzene undergo an alkylation reaction? Write an equation for the reaction between benzene and chloroethane **(A level only)**

React benzene with a haloalkane in the presence of a halogen carrier (e.g. $AlCl_3$):

$$C_6H_6 + C_2H_5Cl \rightarrow C_6H_5(C_2H_5) + HCl$$

How does the halogen carrier generate the electrophile when benzene reacts with a haloalkane?

How does the halogen carrier generate the electrophile when benzene reacts with a haloalkane?

- Halogen carrier reacts with haloalkane to generate electrophile:
  $AlCl_3 + C_2H_5Cl \rightarrow AlCl_4^- + C_2H_5^+$
- $AlCl_4^-$ reacts with the proton expelled from the intermediate to regenerate the halogen carrier:
  $AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$

How does benzene undergo an acylation reaction? Write an equation for the reaction between benzene and ethanoyl chloride **(A level only)**

How does benzene undergo an acylation reaction? Write an equation for the reaction between benzene and ethanoyl chloride **(A level only)**

Reflux benzene with an acyl chloride in the presence of a halogen carrier (i.e. $AlCl_3$):

$$C_6H_6 + CH_3COCl \rightarrow C_6H_5COCH_3 + HCl$$

How does the halogen carrier generate the electrophile when benzene reacts with an acyl chloride? **(A level only)**

How does the halogen carrier generate the electrophile when benzene reacts with an acyl chloride? **(A level only)**

- Halogen carrier reacts with acyl chloride to generate electrophile:
  $AlCl_3 + CH_3COCl \rightarrow AlCl_4^- + CH_3CO^+$
- $AlCl_4^-$ reacts with the proton expelled from the intermediate to regenerate the halogen carrier:
  $AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$

How does benzene undergo addition reactions with hydrogen? **(A level only)**

How does benzene undergo addition reactions with hydrogen? **(A level only)**

$$C_6H_6 + 3H_2 \rightarrow C_6H_{12}$$

- Nickel catalyst
- Heated to around 150°C
- High pressure
- These conditions are required because this reaction has a high activation energy.

How is the side chain of methylbenzene completely oxidised to give benzoic acid? **(A level only)**

How is the side chain of methylbenzene completely oxidised to give benzoic acid? **(A level only)**

- Alkyl groups attached to a benzene ring are oxidised fairly easily when heated under reflux with alkaline potassium manganate solution.
- Purple solution → Dark brown precipitate of MnO_2
- Dilute sulfuric acid is then added.
- Overall, methylbenzene is oxidised to benzoic acid.

How does the ring of delocalisation affect the reactions of benzene? **(A level only)**

How does the ring of delocalisation affect the reactions of benzene? **(A level only)**

- Electron density is relatively low so there is weak attraction to electrophiles.
- This means benzene is unable to undergo electrophilic addition reactions and will slowly undergo electrophilic substitution reactions.
- If benzene was to undergo addition reactions it would permanently break the delocalisation- energetics would be against this happening.

Compare the reactivity of chlorobenzene to chloroalkanes **(A level only)**

Compare the reactivity of chlorobenzene to chloroalkanes **(A level only)**

- The C-Cl bond in chlorobenzene is stronger than expected. One of the lone pairs on the chlorine atom interacts with the delocalised ring electrons, strengthening the bond.
- This means the bond is harder to break and hence requires more energy to overcome.
- This means chlorobenzene is less reactive than chloroalkanes.

How can you tell whether a substitution reaction by a halogen will occur in the benzene ring or on the side chain?

(A level only)

How can you tell whether a substitution reaction by a halogen will occur in the benzene ring or on the side chain? **(A level only)**

For the substitution by a halogen:

- If UV light is present and a catalyst is absent: substitution takes place on the side chain.
- If a catalyst is present and UV light is absent: substitution takes place in the ring.