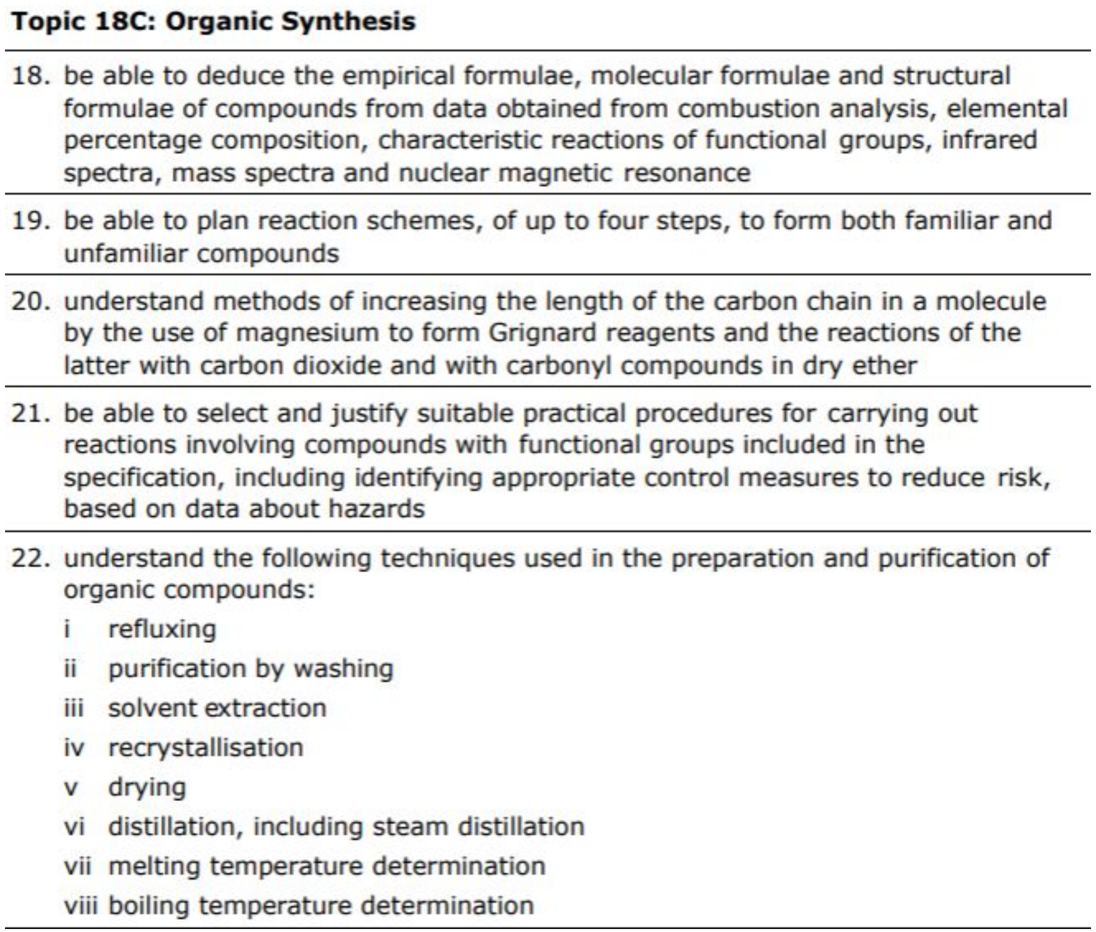
Organic Synthesis

Material Covered

Organic Synthesis

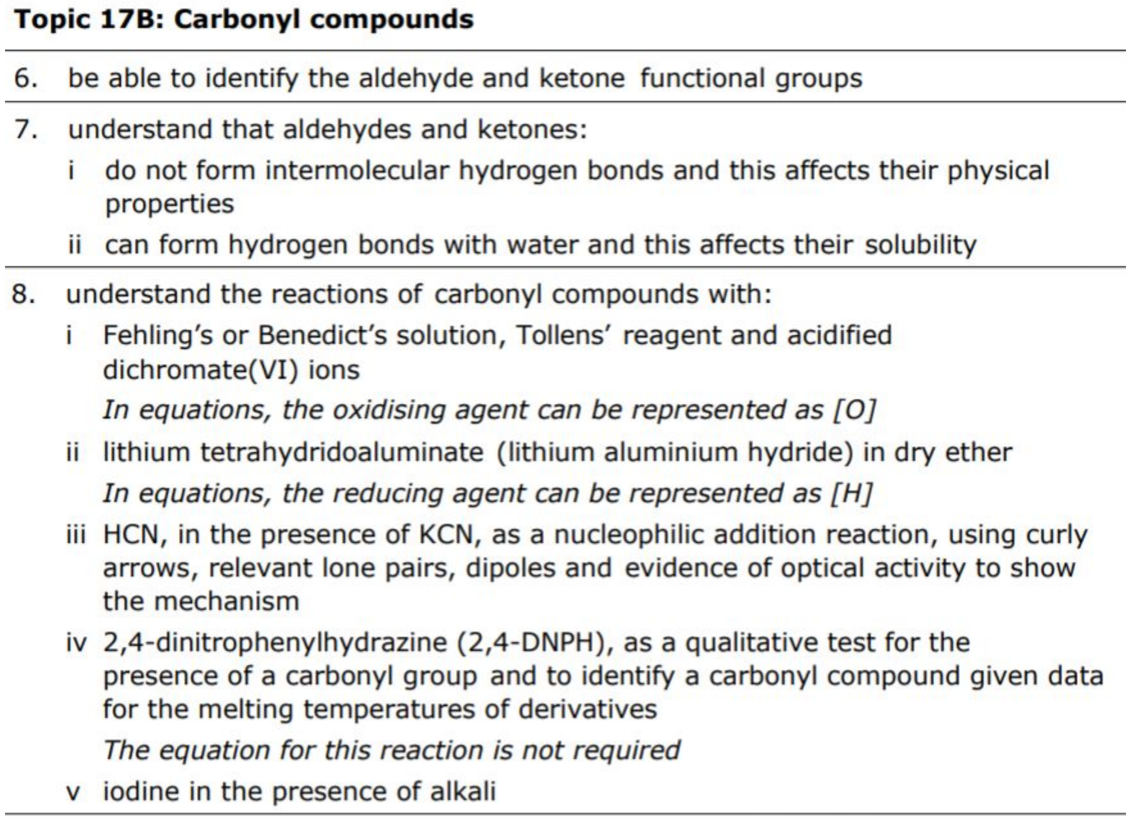
1. Esters and Acid Anhydrides
2. Benzene :
    1. Nitration and Amine Formation
    2. Acylation and Halogenation
3. Amino Acids and Proteins

Edexcel



Topic 18C: Organic Synthesis

18. be able to deduce the empirical formulae, molecular formulae and structural formulae of compounds from data obtained from combustion analysis, elemental percentage composition, characteristic reactions of functional groups, infrared spectra, mass spectra and nuclear magnetic resonance
19. be able to plan reaction schemes, of up to four steps, to form both familiar and unfamiliar compounds
20. understand methods of increasing the length of the carbon chain in a molecule by the use of magnesium to form Grignard reagents and the reactions of the latter with carbon dioxide and with carbonyl compounds in dry ether
21. be able to select and justify suitable practical procedures for carrying out reactions involving compounds with functional groups included in the specification, including identifying appropriate control measures to reduce risk, based on data about hazards
22. understand the following techniques used in the preparation and purification of organic compounds:
    - i refluxing
    - ii purification by washing
    - iii solvent extraction
    - iv recrystallisation
    - v drying
    - vi distillation, including steam distillation
    - vii melting temperature determination
    - viii boiling temperature determination



Topic 17B: Carbonyl compounds

6. be able to identify the aldehyde and ketone functional groups
7. understand that aldehydes and ketones:
    - i do not form intermolecular hydrogen bonds and this affects their physical properties
    - ii can form hydrogen bonds with water and this affects their solubility
8. understand the reactions of carbonyl compounds with:
    - i Fehling's or Benedict's solution, Tollens' reagent and acidified dichromate(VI) ions

      In equations, the oxidising agent can be represented as [O]
    - ii lithium tetrahydridoaluminate (lithium aluminium hydride) in dry ether

      In equations, the reducing agent can be represented as [H]
    - iii HCN, in the presence of KCN, as a nucleophilic addition reaction, using curly arrows, relevant lone pairs, dipoles and evidence of optical activity to show the mechanism
    - iv 2,4-dinitrophenylhydrazine (2,4-DNPH), as a qualitative test for the presence of a carbonyl group and to identify a carbonyl compound given data for the melting temperatures of derivatives

      The equation for this reaction is not required
    - v iodine in the presence of alkali

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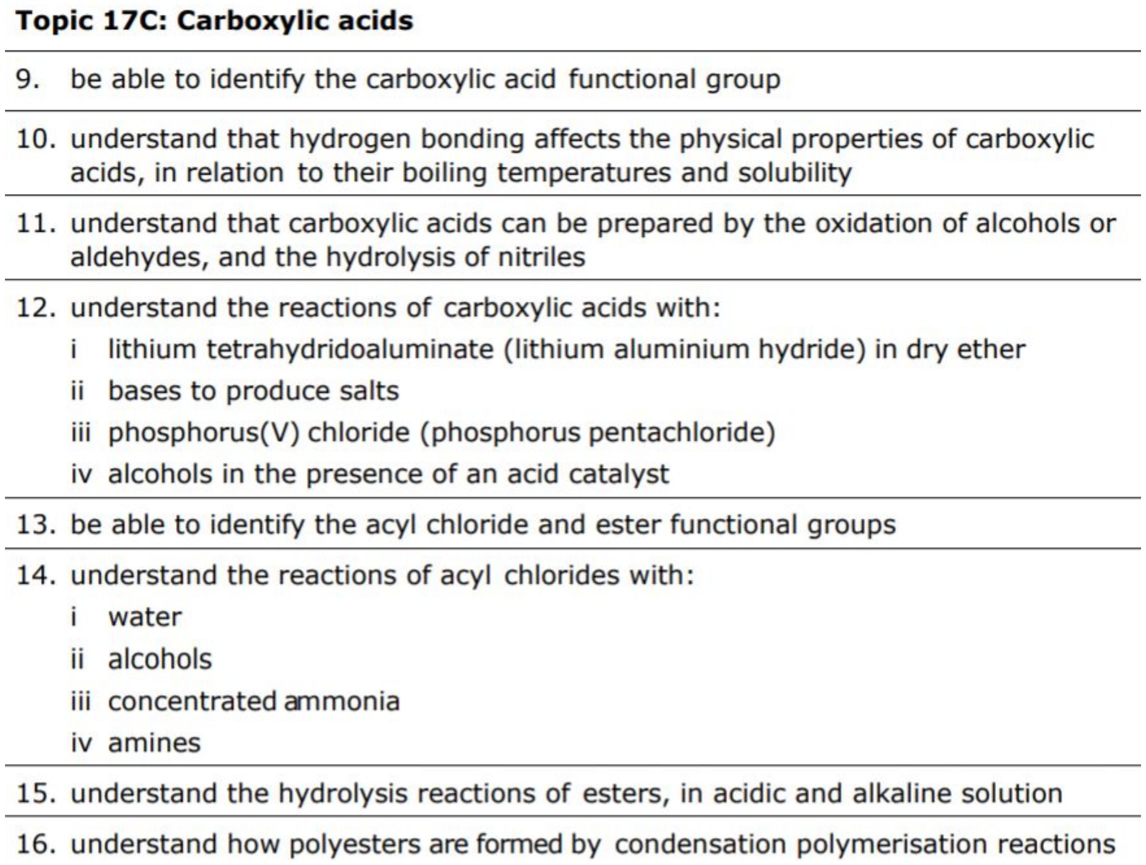
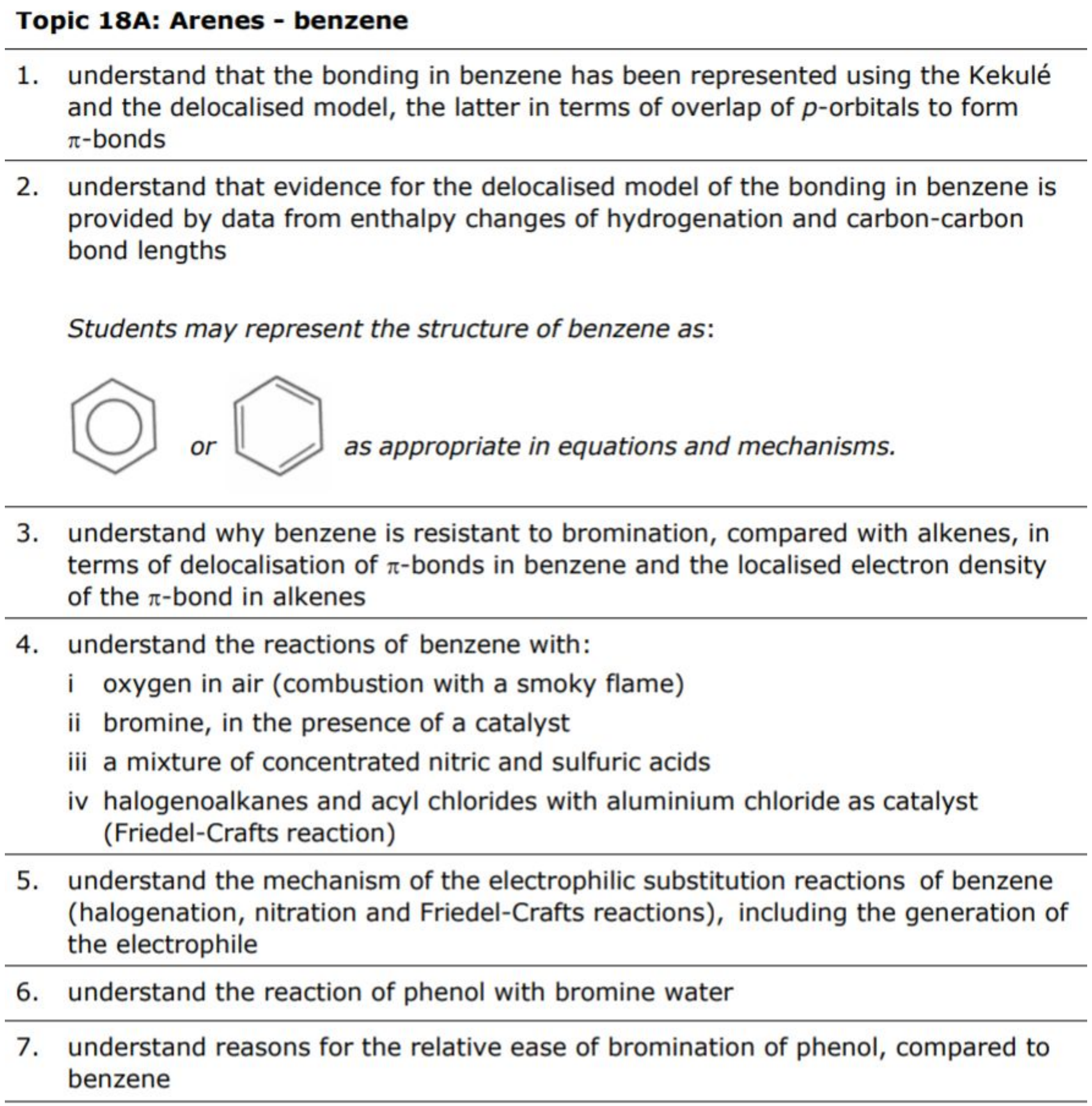


Topic 17C: Carboxylic acids

9. be able to identify the carboxylic acid functional group
10. understand that hydrogen bonding affects the physical properties of carboxylic acids, in relation to their boiling temperatures and solubility
11. understand that carboxylic acids can be prepared by the oxidation of alcohols or aldehydes, and the hydrolysis of nitriles
12. understand the reactions of carboxylic acids with:
    - i lithium tetrahydridoaluminate (lithium aluminium hydride) in dry ether
    - ii bases to produce salts
    - iii phosphorus(V) chloride (phosphorus pentachloride)
    - iv alcohols in the presence of an acid catalyst
13. be able to identify the acyl chloride and ester functional groups
14. understand the reactions of acyl chlorides with:
    - i water
    - ii alcohols
    - iii concentrated ammonia
    - iv amines
15. understand the hydrolysis reactions of esters, in acidic and alkaline solution
16. understand how polyesters are formed by condensation polymerisation reactions



Topic 18A: Arenes - benzene

1. understand that the bonding in benzene has been represented using the Kekulé and the delocalised model, the latter in terms of overlap of *p*-orbitals to form π-bonds
2. understand that evidence for the delocalised model of the bonding in benzene is provided by data from enthalpy changes of hydrogenation and carbon-carbon bond lengths

   Students may represent the structure of benzene as:

   or *as appropriate in equations and mechanisms.*
3. understand why benzene is resistant to bromination, compared with alkenes, in terms of delocalisation of π-bonds in benzene and the localised electron density of the π-bond in alkenes
4. understand the reactions of benzene with:
    - i oxygen in air (combustion with a smoky flame)
    - ii bromine, in the presence of a catalyst
    - iii a mixture of concentrated nitric and sulfuric acids
    - iv halogenoalkanes and acyl chlorides with aluminium chloride as catalyst (Friedel-Crafts reaction)
5. understand the mechanism of the electrophilic substitution reactions of benzene (halogenation, nitration and Friedel-Crafts reactions), including the generation of the electrophile
6. understand the reaction of phenol with bromine water
7. understand reasons for the relative ease of bromination of phenol, compared to benzene

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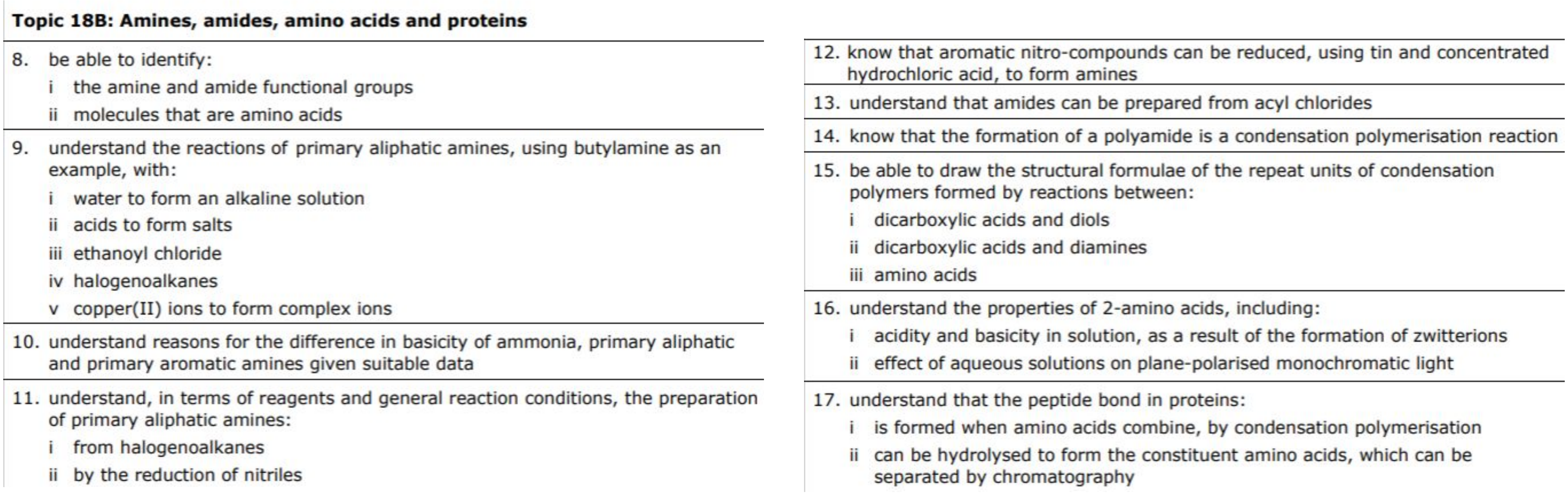


Topic 18B: Amines, amides, amino acids and proteins

8. be able to identify:
   - i the amine and amide functional groups
   - ii molecules that are amino acids

9. understand the reactions of primary aliphatic amines, using butylamine as an example, with:
   - i water to form an alkaline solution
   - ii acids to form salts
   - iii ethanoyl chloride
   - iv halogenoalkanes
   - v copper(II) ions to form complex ions

10. understand reasons for the difference in basicity of ammonia, primary aliphatic and primary aromatic amines given suitable data

11. understand, in terms of reagents and general reaction conditions, the preparation of primary aliphatic amines:
    - i from halogenoalkanes
    - ii by the reduction of nitriles

12. know that aromatic nitro-compounds can be reduced, using tin and concentrated hydrochloric acid, to form amines

13. understand that amides can be prepared from acyl chlorides

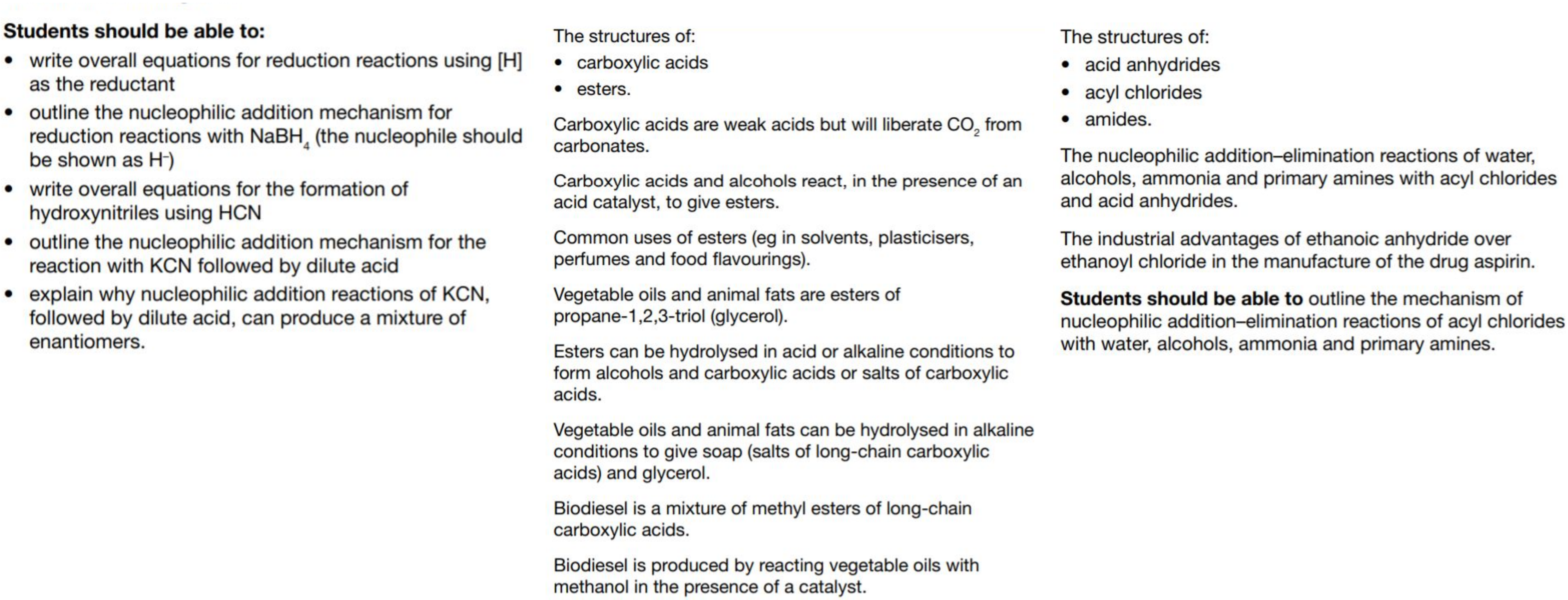
14. know that the formation of a polyamide is a condensation polymerisation reaction

15. be able to draw the structural formulae of the repeat units of condensation polymers formed by reactions between:
    - i dicarboxylic acids and diols
    - ii dicarboxylic acids and diamines
    - iii amino acids

16. understand the properties of 2-amino acids, including:
    - i acidity and basicity in solution, as a result of the formation of zwitterions
    - ii effect of aqueous solutions on plane-polarised monochromatic light

17. understand that the peptide bond in proteins:
    - i is formed when amino acids combine, by condensation polymerisation
    - ii can be hydrolysed to form the constituent amino acids, which can be separated by chromatography

AQA



Students should be able to:

- write overall equations for reduction reactions using [H] as the reductant
- outline the nucleophilic addition mechanism for reduction reactions with $NaBH_4$ (the nucleophile should be shown as H^-)
- write overall equations for the formation of hydroxynitriles using HCN
- outline the nucleophilic addition mechanism for the reaction with KCN followed by dilute acid
- explain why nucleophilic addition reactions of KCN, followed by dilute acid, can produce a mixture of enantiomers.

The structures of:

- carboxylic acids
- esters.

Carboxylic acids are weak acids but will liberate CO_2 from carbonates.

Carboxylic acids and alcohols react, in the presence of an acid catalyst, to give esters.

Common uses of esters (eg in solvents, plasticisers, perfumes and food flavourings).

Vegetable oils and animal fats are esters of propane-1,2,3-triol (glycerol).

Esters can be hydrolysed in acid or alkaline conditions to form alcohols and carboxylic acids or salts of carboxylic acids.

Vegetable oils and animal fats can be hydrolysed in alkaline conditions to give soap (salts of long-chain carboxylic acids) and glycerol.

Biodiesel is a mixture of methyl esters of long-chain carboxylic acids.

Biodiesel is produced by reacting vegetable oils with methanol in the presence of a catalyst.

The structures of:

- acid anhydrides
- acyl chlorides
- amides.

The nucleophilic addition–elimination reactions of water, alcohols, ammonia and primary amines with acyl chlorides and acid anhydrides.

The industrial advantages of ethanoic anhydride over ethanoyl chloride in the manufacture of the drug aspirin.

Students should be able to outline the mechanism of nucleophilic addition–elimination reactions of acyl chlorides with water, alcohols, ammonia and primary amines.

Specification Reference

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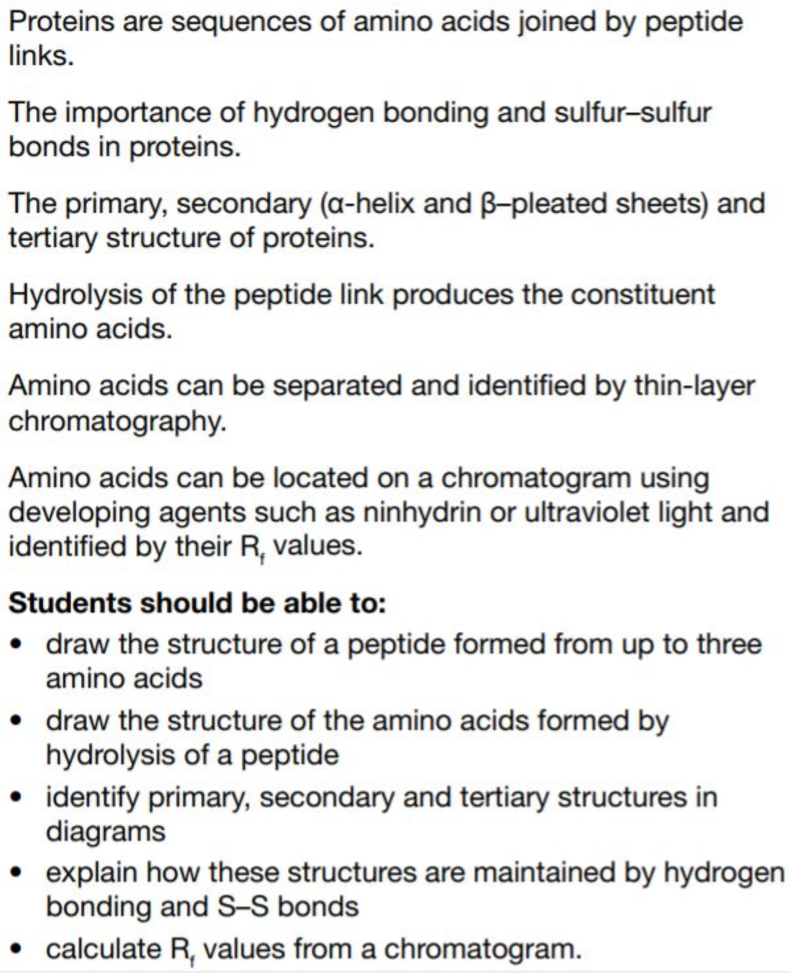


Proteins are sequences of amino acids joined by peptide links.

The importance of hydrogen bonding and sulfur–sulfur bonds in proteins.

The primary, secondary (α-helix and β–pleated sheets) and tertiary structure of proteins.

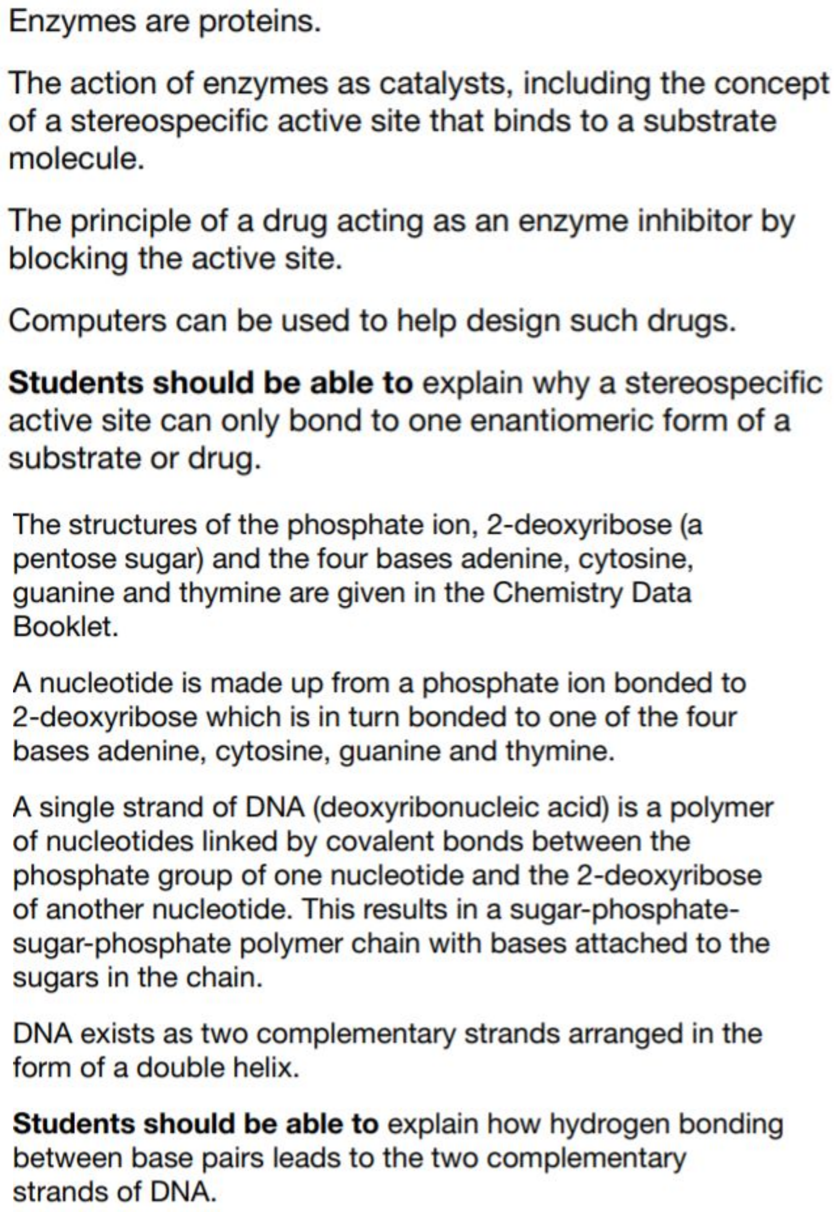
Hydrolysis of the peptide link produces the constituent amino acids.

Amino acids can be separated and identified by thin-layer chromatography.

Amino acids can be located on a chromatogram using developing agents such as ninhydrin or ultraviolet light and identified by their R_f values.

Students should be able to:

- draw the structure of a peptide formed from up to three amino acids
- draw the structure of the amino acids formed by hydrolysis of a peptide
- identify primary, secondary and tertiary structures in diagrams
- explain how these structures are maintained by hydrogen bonding and S–S bonds
- calculate R_f values from a chromatogram.



Enzymes are proteins.

The action of enzymes as catalysts, including the concept of a stereospecific active site that binds to a substrate molecule.

The principle of a drug acting as an enzyme inhibitor by blocking the active site.

Computers can be used to help design such drugs.

Students should be able to explain why a stereospecific active site can only bond to one enantiomeric form of a substrate or drug.

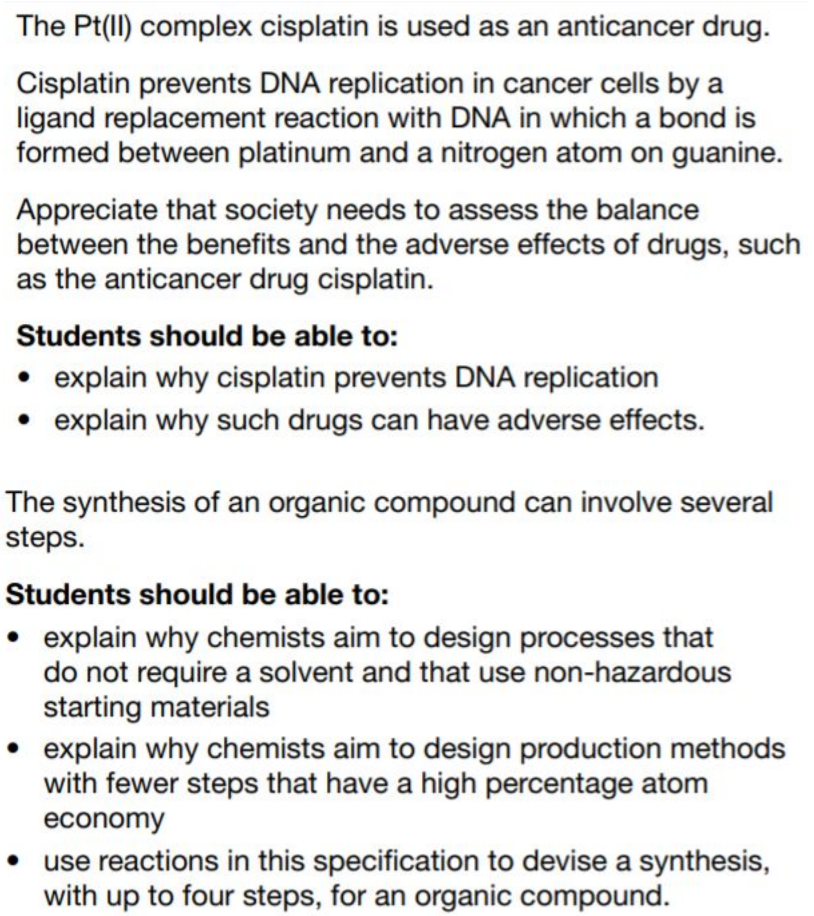
The structures of the phosphate ion, 2-deoxyribose (a pentose sugar) and the four bases adenine, cytosine, guanine and thymine are given in the Chemistry Data Booklet.

A nucleotide is made up from a phosphate ion bonded to 2-deoxyribose which is in turn bonded to one of the four bases adenine, cytosine, guanine and thymine.

A single strand of DNA (deoxyribonucleic acid) is a polymer of nucleotides linked by covalent bonds between the phosphate group of one nucleotide and the 2-deoxyribose of another nucleotide. This results in a sugar-phosphate-sugar-phosphate polymer chain with bases attached to the sugars in the chain.

DNA exists as two complementary strands arranged in the form of a double helix.

Students should be able to explain how hydrogen bonding between base pairs leads to the two complementary strands of DNA.



The Pt(II) complex cisplatin is used as an anticancer drug.

Cisplatin prevents DNA replication in cancer cells by a ligand replacement reaction with DNA in which a bond is formed between platinum and a nitrogen atom on guanine.

Appreciate that society needs to assess the balance between the benefits and the adverse effects of drugs, such as the anticancer drug cisplatin.

Students should be able to:

- explain why cisplatin prevents DNA replication
- explain why such drugs can have adverse effects.

The synthesis of an organic compound can involve several steps.

Students should be able to:

- explain why chemists aim to design processes that do not require a solvent and that use non-hazardous starting materials
- explain why chemists aim to design production methods with fewer steps that have a high percentage atom economy
- use reactions in this specification to devise a synthesis, with up to four steps, for an organic compound.

Specification Reference

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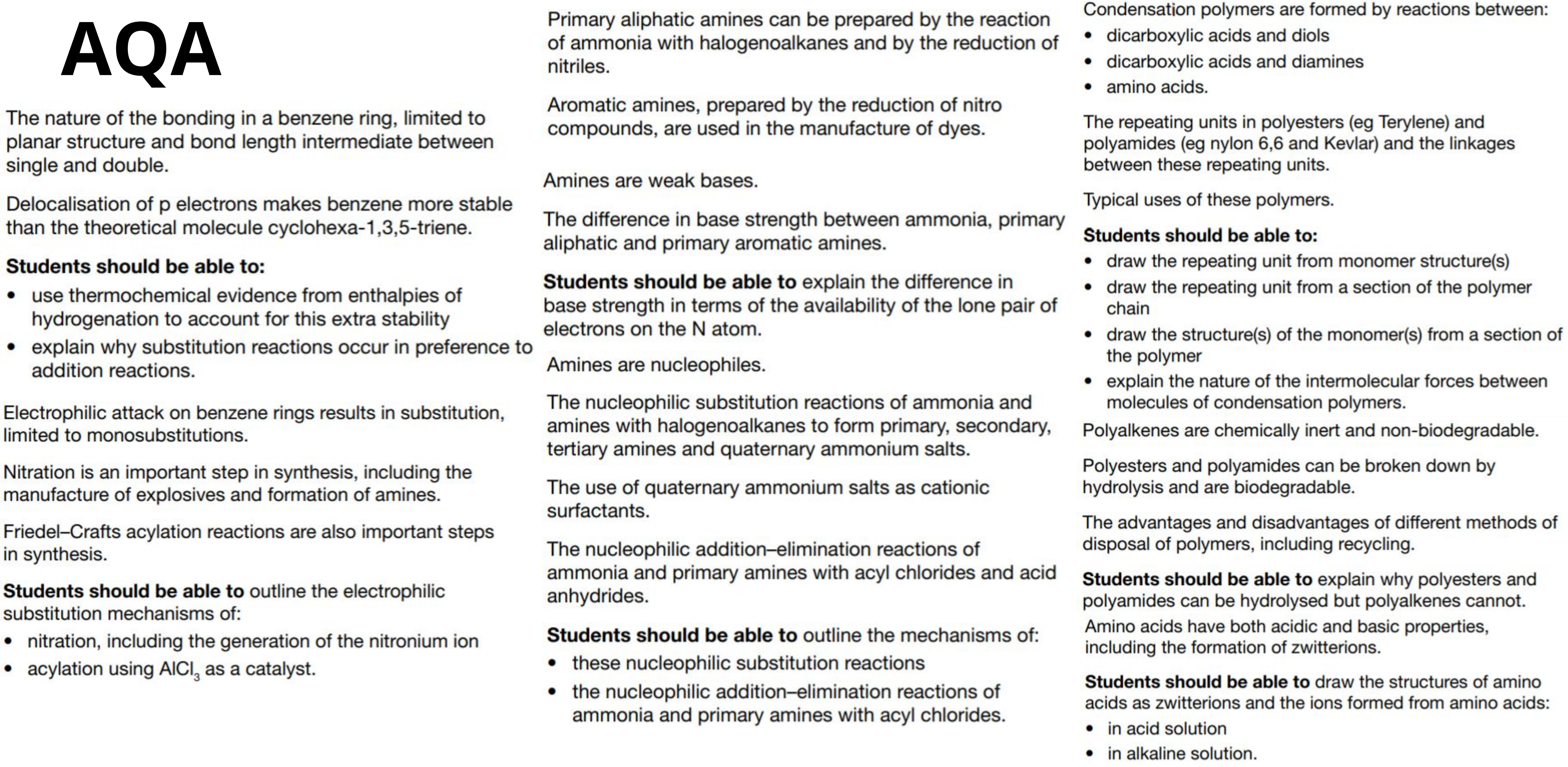

The nature of the bonding in a benzene ring, limited to planar structure and bond length intermediate between single and double.

Delocalisation of p electrons makes benzene more stable than the theoretical molecule cyclohexa-1,3,5-triene.

Students should be able to:

- use thermochemical evidence from enthalpies of hydrogenation to account for this extra stability
- explain why substitution reactions occur in preference to addition reactions.

Electrophilic attack on benzene rings results in substitution, limited to monosubstitutions.

Nitration is an important step in synthesis, including the manufacture of explosives and formation of amines.

Friedel–Crafts acylation reactions are also important steps in synthesis.

Students should be able to outline the electrophilic substitution mechanisms of:

- nitration, including the generation of the nitronium ion
- acylation using $AlCl_3$ as a catalyst.

Primary aliphatic amines can be prepared by the reaction of ammonia with halogenoalkanes and by the reduction of nitriles.

Aromatic amines, prepared by the reduction of nitro compounds, are used in the manufacture of dyes.

Amines are weak bases.

The difference in base strength between ammonia, primary aliphatic and primary aromatic amines.

Students should be able to explain the difference in base strength in terms of the availability of the lone pair of electrons on the N atom.

Amines are nucleophiles.

The nucleophilic substitution reactions of ammonia and amines with halogenoalkanes to form primary, secondary, tertiary amines and quaternary ammonium salts.

The use of quaternary ammonium salts as cationic surfactants.

The nucleophilic addition–elimination reactions of ammonia and primary amines with acyl chlorides and acid anhydrides.

Students should be able to outline the mechanisms of:

- these nucleophilic substitution reactions
- the nucleophilic addition–elimination reactions of ammonia and primary amines with acyl chlorides.

Condensation polymers are formed by reactions between:

- dicarboxylic acids and diols
- dicarboxylic acids and diamines
- amino acids.

The repeating units in polyesters (eg Terylene) and polyamides (eg nylon 6,6 and Kevlar) and the linkages between these repeating units.

Typical uses of these polymers.

Students should be able to:

- draw the repeating unit from monomer structure(s)
- draw the repeating unit from a section of the polymer chain
- draw the structure(s) of the monomer(s) from a section of the polymer
- explain the nature of the intermolecular forces between molecules of condensation polymers.

Polyalkenes are chemically inert and non-biodegradable.

Polyesters and polyamides can be broken down by hydrolysis and are biodegradable.

The advantages and disadvantages of different methods of disposal of polymers, including recycling.

Students should be able to explain why polyesters and polyamides can be hydrolysed but polyalkenes cannot.

Amino acids have both acidic and basic properties, including the formation of zwitterions.

Students should be able to draw the structures of amino acids as zwitterions and the ions formed from amino acids:

- in acid solution
- in alkaline solution.

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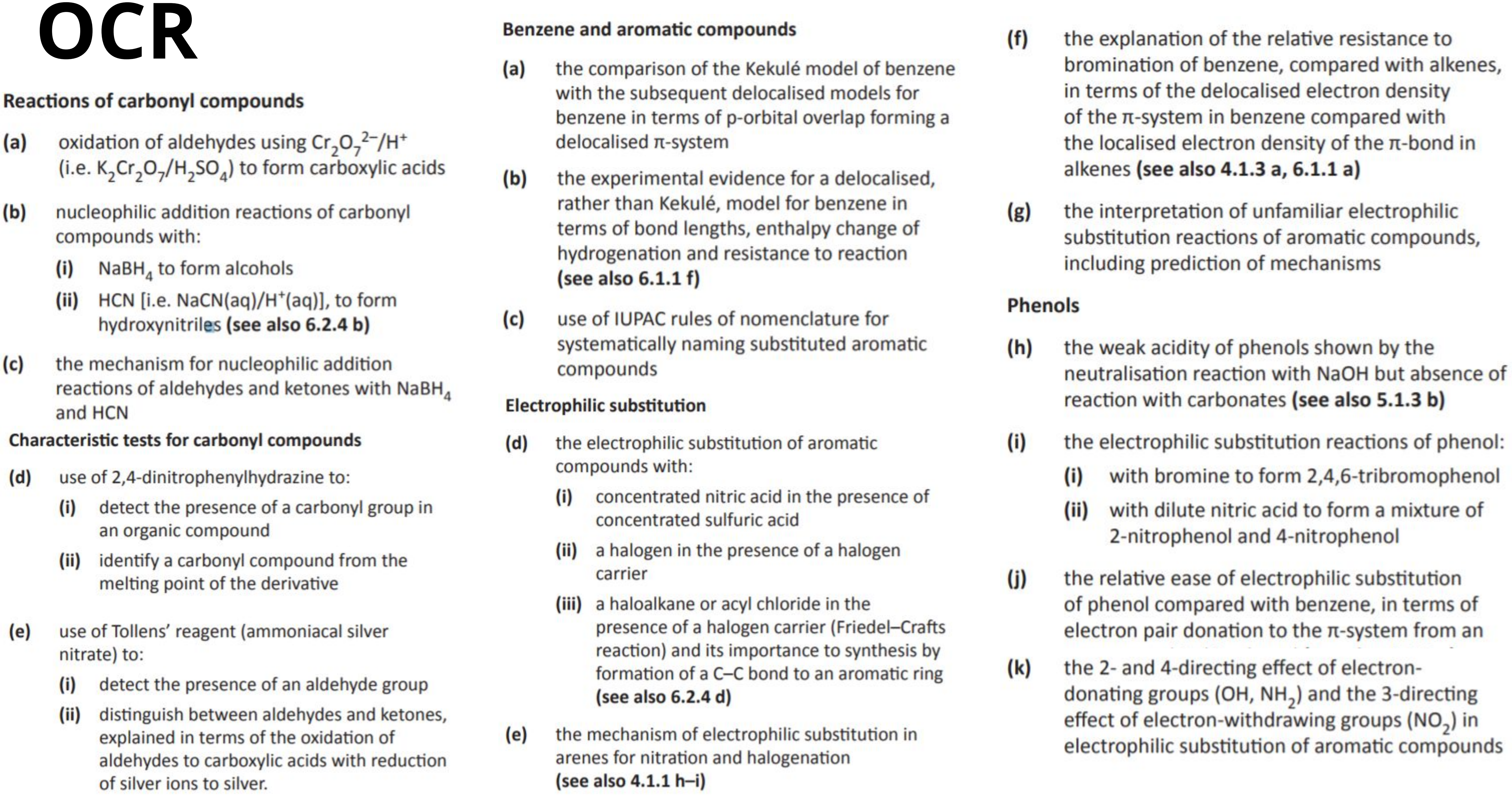

Reactions of carbonyl compounds

(a) oxidation of aldehydes using $Cr_2O_7^{2-}/H^+$ (i.e. $K_2Cr_2O_7/H_2SO_4$) to form carboxylic acids

(b) nucleophilic addition reactions of carbonyl compounds with:

- **(i)** $NaBH_4$ to form alcohols
- **(ii)** HCN [i.e. NaCN(aq)/H^+(aq)], to form hydroxynitriles **(see also 6.2.4 b)**

(c) the mechanism for nucleophilic addition reactions of aldehydes and ketones with $NaBH_4$ and HCN

Characteristic tests for carbonyl compounds

(d) use of 2,4-dinitrophenylhydrazine to:

- **(i)** detect the presence of a carbonyl group in an organic compound
- **(ii)** identify a carbonyl compound from the melting point of the derivative

(e) use of Tollens' reagent (ammoniacal silver nitrate) to:

- **(i)** detect the presence of an aldehyde group
- **(ii)** distinguish between aldehydes and ketones, explained in terms of the oxidation of aldehydes to carboxylic acids with reduction of silver ions to silver.

Benzene and aromatic compounds

(a) the comparison of the Kekulé model of benzene with the subsequent delocalised models for benzene in terms of p-orbital overlap forming a delocalised π-system

(b) the experimental evidence for a delocalised, rather than Kekulé, model for benzene in terms of bond lengths, enthalpy change of hydrogenation and resistance to reaction **(see also 6.1.1 f)**

(c) use of IUPAC rules of nomenclature for systematically naming substituted aromatic compounds

Electrophilic substitution

(d) the electrophilic substitution of aromatic compounds with:

- **(i)** concentrated nitric acid in the presence of concentrated sulfuric acid
- **(ii)** a halogen in the presence of a halogen carrier
- **(iii)** a haloalkane or acyl chloride in the presence of a halogen carrier (Friedel–Crafts reaction) and its importance to synthesis by formation of a C–C bond to an aromatic ring **(see also 6.2.4 d)**

(e) the mechanism of electrophilic substitution in arenes for nitration and halogenation **(see also 4.1.1 h–i)**

(f) the explanation of the relative resistance to bromination of benzene, compared with alkenes, in terms of the delocalised electron density of the π-system in benzene compared with the localised electron density of the π-bond in alkenes **(see also 4.1.3 a, 6.1.1 a)**

(g) the interpretation of unfamiliar electrophilic substitution reactions of aromatic compounds, including prediction of mechanisms

Phenols

(h) the weak acidity of phenols shown by the neutralisation reaction with NaOH but absence of reaction with carbonates **(see also 5.1.3 b)**

(i) the electrophilic substitution reactions of phenol:

- **(i)** with bromine to form 2,4,6-tribromophenol
- **(ii)** with dilute nitric acid to form a mixture of 2-nitrophenol and 4-nitrophenol

(j) the relative ease of electrophilic substitution of phenol compared with benzene, in terms of electron pair donation to the π-system from an

(k) the 2- and 4-directing effect of electron-donating groups (OH, NH_2) and the 3-directing effect of electron-withdrawing groups (NO_2) in electrophilic substitution of aromatic compounds

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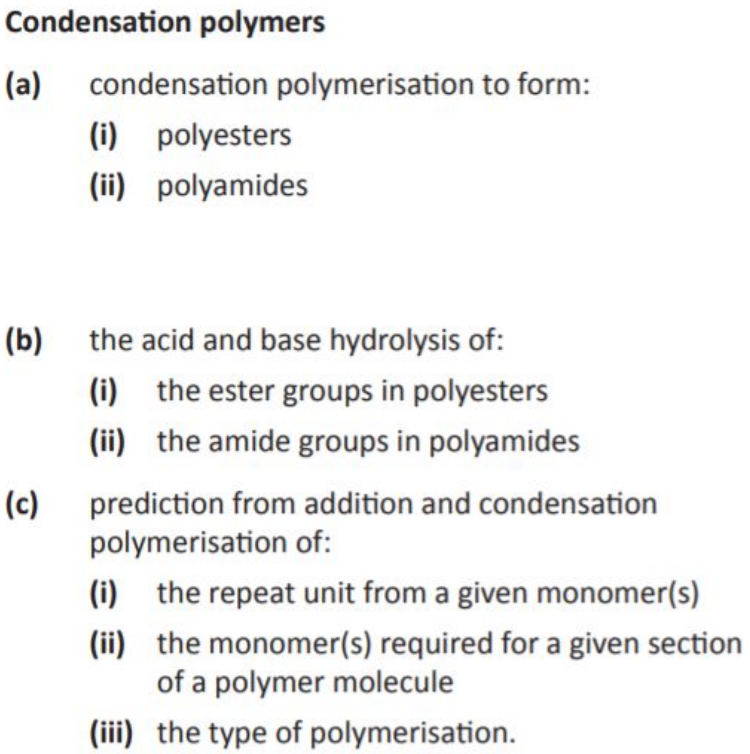
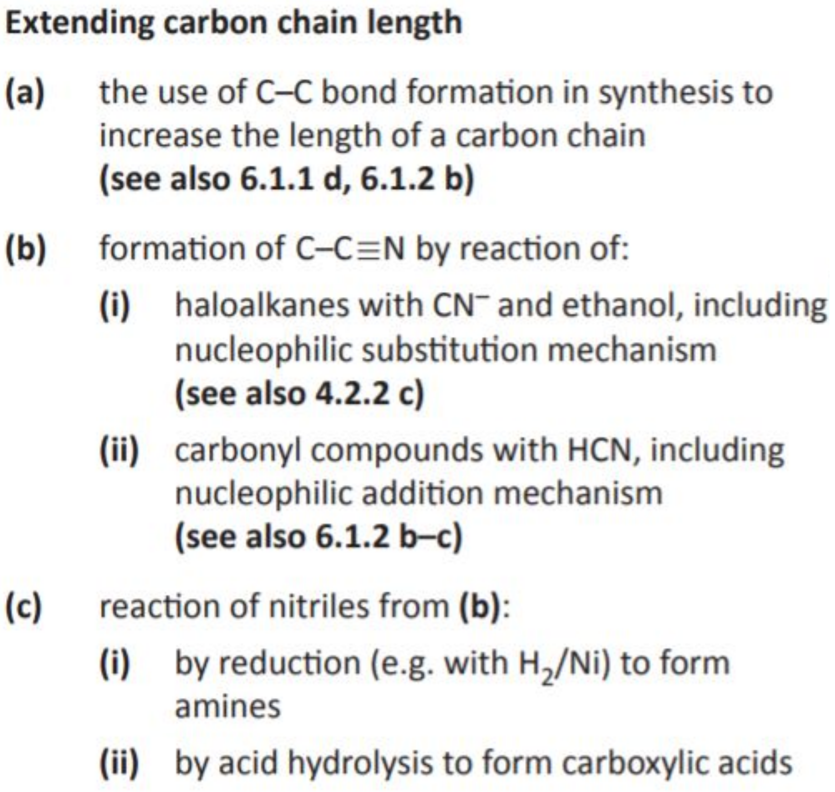


Condensation polymers

(a) condensation polymerisation to form:
  - **(i)** polyesters
  - **(ii)** polyamides

(b) the acid and base hydrolysis of:
  - **(i)** the ester groups in polyesters
  - **(ii)** the amide groups in polyamides

(c) prediction from addition and condensation polymerisation of:
  - **(i)** the repeat unit from a given monomer(s)
  - **(ii)** the monomer(s) required for a given section of a polymer molecule
  - **(iii)** the type of polymerisation.

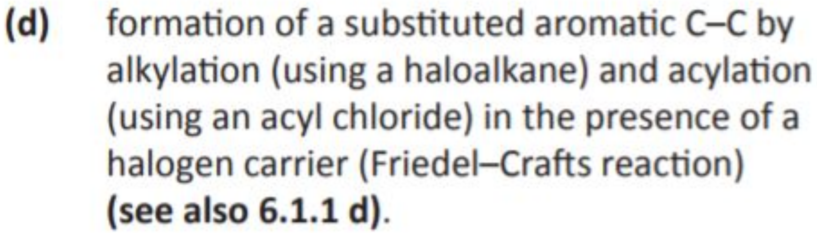


Extending carbon chain length

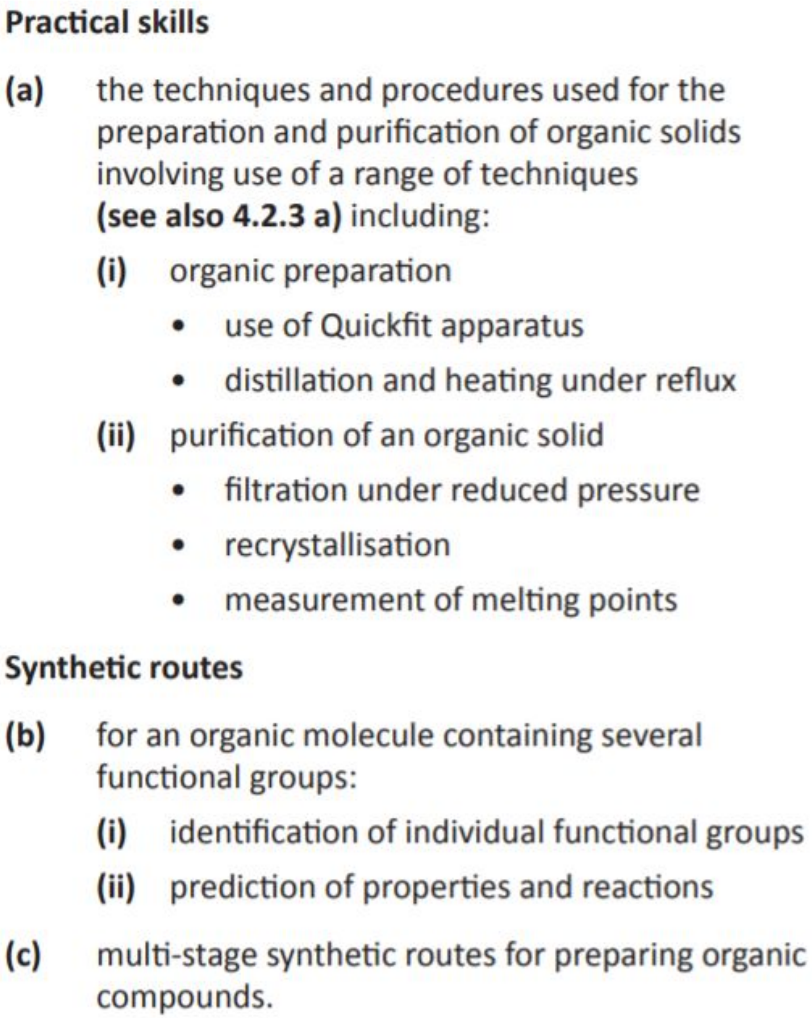
(a) the use of C–C bond formation in synthesis to increase the length of a carbon chain **(see also 6.1.1 d, 6.1.2 b)**

(b) formation of C–C≡N by reaction of:
  - **(i)** haloalkanes with CN^- and ethanol, including nucleophilic substitution mechanism **(see also 4.2.2 c)**
  - **(ii)** carbonyl compounds with HCN, including nucleophilic addition mechanism **(see also 6.1.2 b–c)**

(c) reaction of nitriles from **(b)**:
  - **(i)** by reduction (e.g. with H_2/Ni) to form amines
  - **(ii)** by acid hydrolysis to form carboxylic acids



(d) formation of a substituted aromatic C–C by alkylation (using a haloalkane) and acylation (using an acyl chloride) in the presence of a halogen carrier (Friedel–Crafts reaction) **(see also 6.1.1 d)**.



Practical skills

(a) the techniques and procedures used for the preparation and purification of organic solids involving use of a range of techniques **(see also 4.2.3 a)** including:
  - **(i)** organic preparation
    - use of Quickfit apparatus
    - distillation and heating under reflux
  - **(ii)** purification of an organic solid
    - filtration under reduced pressure
    - recrystallisation
    - measurement of melting points

Synthetic routes

(b) for an organic molecule containing several functional groups:
  - **(i)** identification of individual functional groups
  - **(ii)** prediction of properties and reactions

(c) multi-stage synthetic routes for preparing organic compounds.

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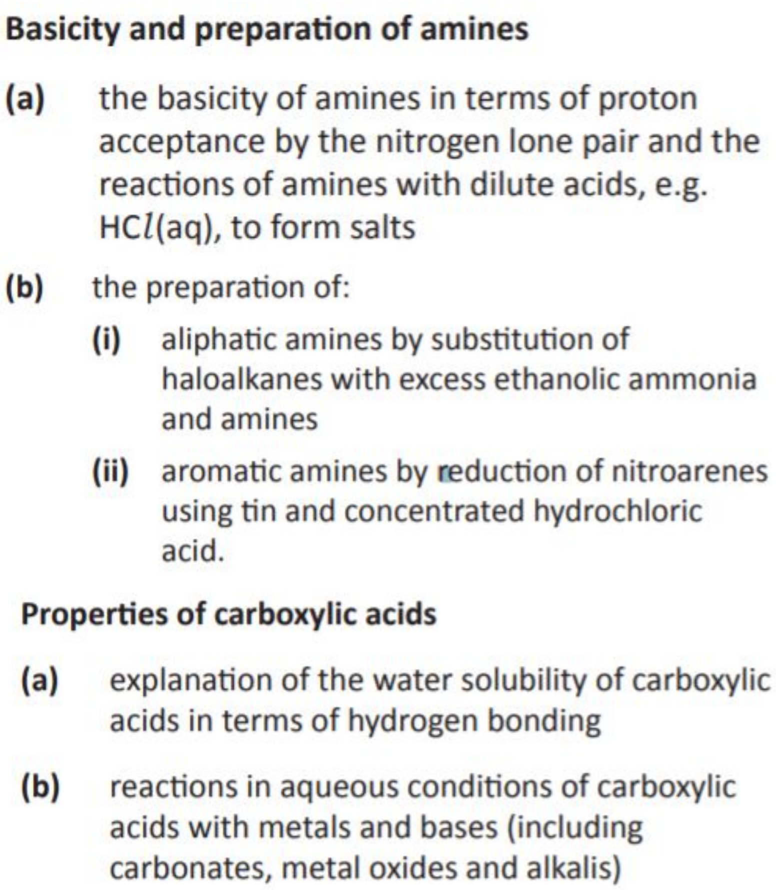


Basicity and preparation of amines

(a) the basicity of amines in terms of proton acceptance by the nitrogen lone pair and the reactions of amines with dilute acids, e.g. HCl(aq), to form salts

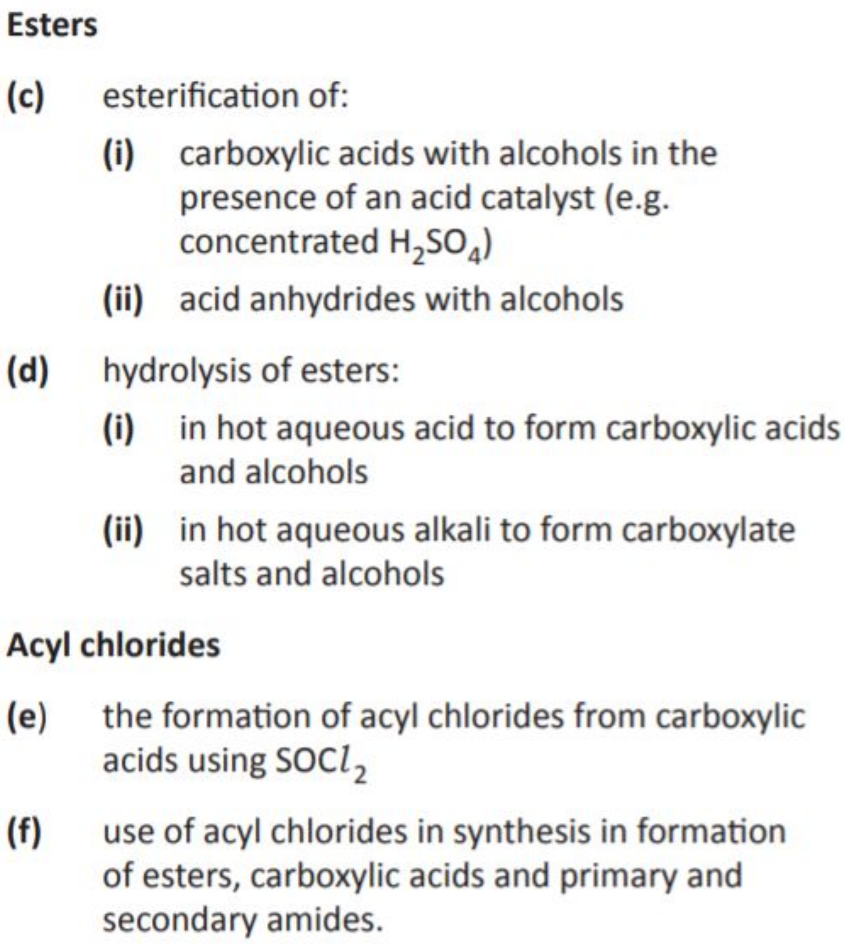
(b) the preparation of:

- **(i)** aliphatic amines by substitution of haloalkanes with excess ethanolic ammonia and amines
- **(ii)** aromatic amines by reduction of nitroarenes using tin and concentrated hydrochloric acid.

Properties of carboxylic acids

(a) explanation of the water solubility of carboxylic acids in terms of hydrogen bonding

(b) reactions in aqueous conditions of carboxylic acids with metals and bases (including carbonates, metal oxides and alkalis)



Esters

(c) esterification of:

- **(i)** carboxylic acids with alcohols in the presence of an acid catalyst (e.g. concentrated H_2SO_4)
- **(ii)** acid anhydrides with alcohols

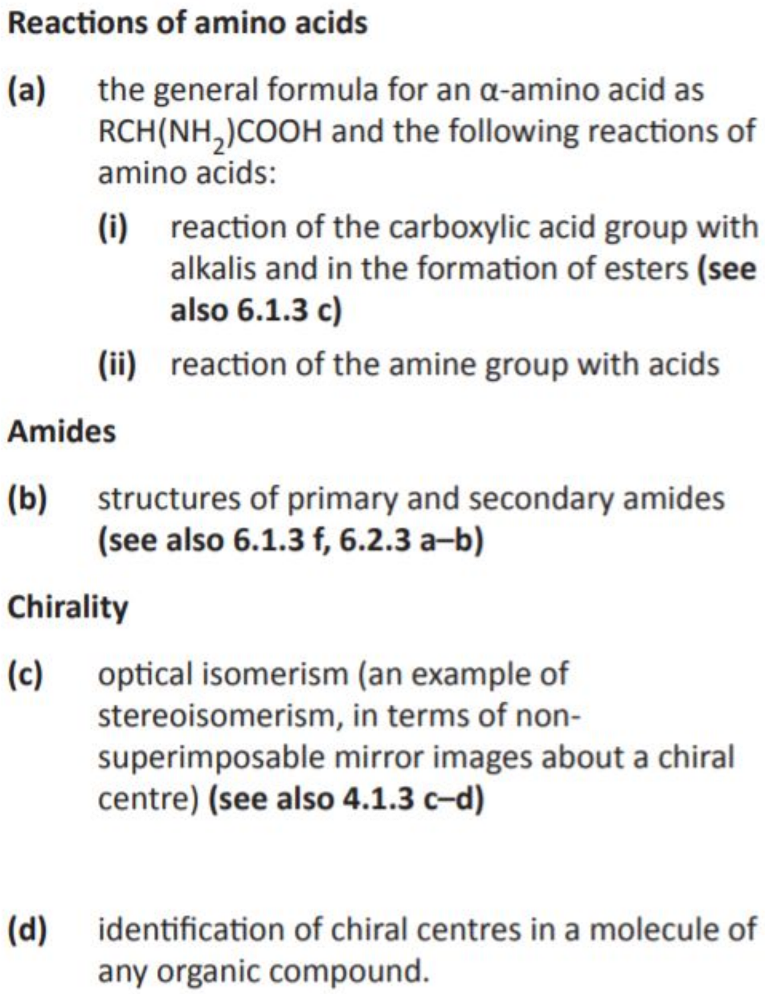
(d) hydrolysis of esters:

- **(i)** in hot aqueous acid to form carboxylic acids and alcohols
- **(ii)** in hot aqueous alkali to form carboxylate salts and alcohols

Acyl chlorides

(e) the formation of acyl chlorides from carboxylic acids using $SOCl_2$

(f) use of acyl chlorides in synthesis in formation of esters, carboxylic acids and primary and secondary amides.



Reactions of amino acids

(a) the general formula for an α-amino acid as $RCH(NH_2)COOH$ and the following reactions of amino acids:

- **(i)** reaction of the carboxylic acid group with alkalis and in the formation of esters **(see also 6.1.3 c)**
- **(ii)** reaction of the amine group with acids

Amides

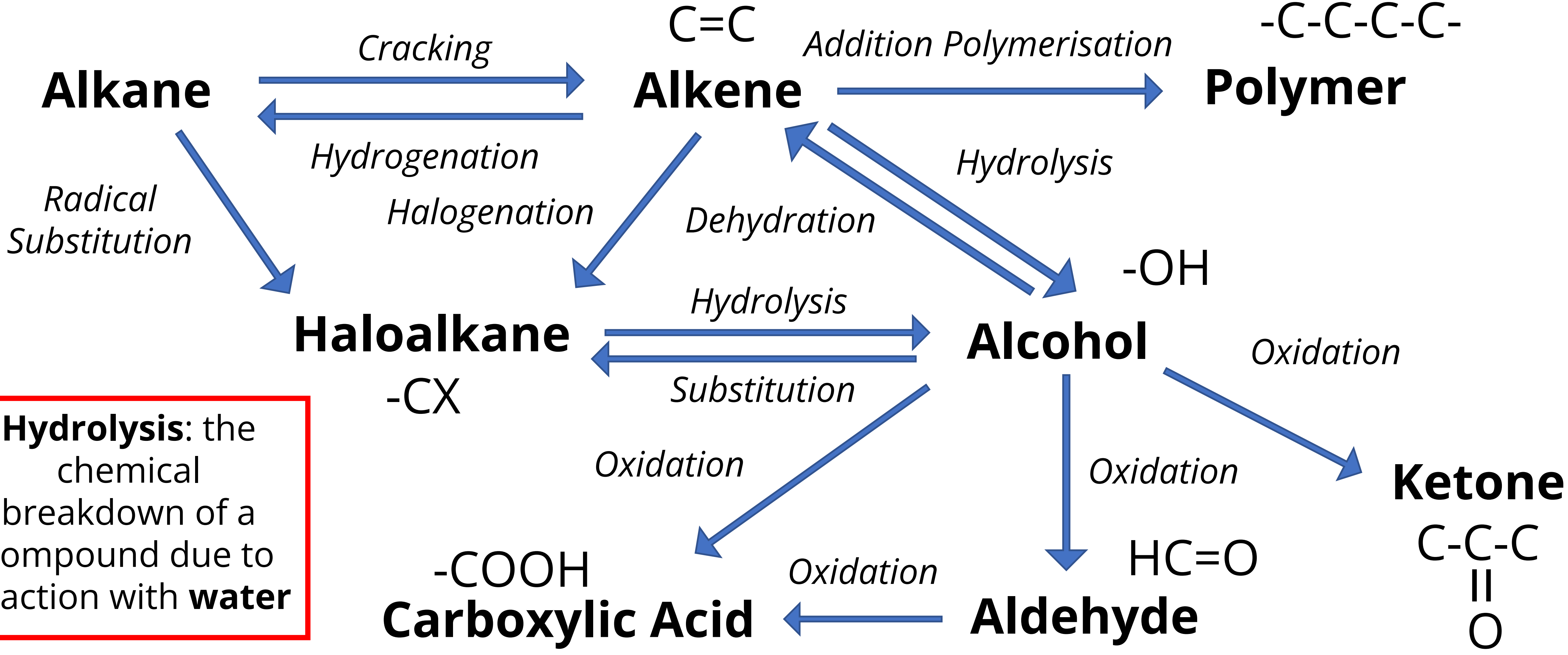
(b) structures of primary and secondary amides **(see also 6.1.3 f, 6.2.3 a–b)**

Chirality

(c) optical isomerism (an example of stereoisomerism, in terms of non-superimposable mirror images about a chiral centre) **(see also 4.1.3 c–d)**

(d) identification of chiral centres in a molecule of any organic compound.

AS Organic Synthesis Overview



$C=C$

Alkene

Cracking

Hydrogenation

Alkane

Addition Polymerisation

$-C-C-C-C-$

Polymer

Radical Substitution

Halogenation

Dehydration

Hydrolysis

Haloalkane

$-CX$

Hydrolysis

Substitution

$-OH$

Alcohol

Oxidation

Oxidation

Oxidation

Ketone

C-C-C
II
O

Oxidation

$-COOH$

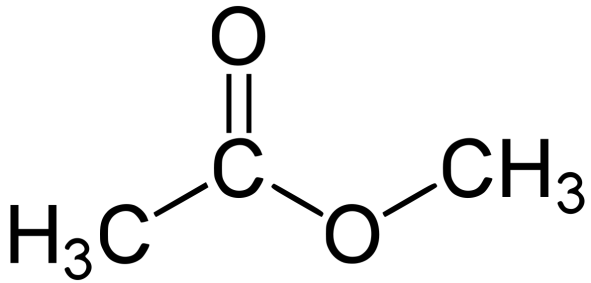
Carboxylic Acid

$HC=O$

Aldehyde

Hydrolysis: the chemical breakdown of a compound due to reaction with **water**

Esters



Esters contain the **functional group R-COO-R’**

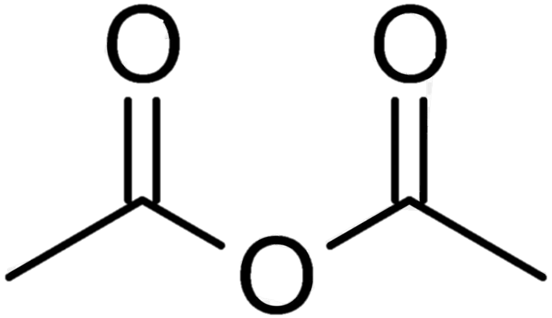
Esters can be **synthesised** in the **reversible reaction** between a **carboxylic acid** and an **alcohol**

Naming an Ester:
The name begins with the R’ group, then the R group with an **–’oate’** suffix

Acid Anhydrides

Acid anhydrides can be formed from the **condensation** of two carboxylic acids.

They are more **reactive** than carboxylic acids, and can also react with **alcohols** to form **esters**

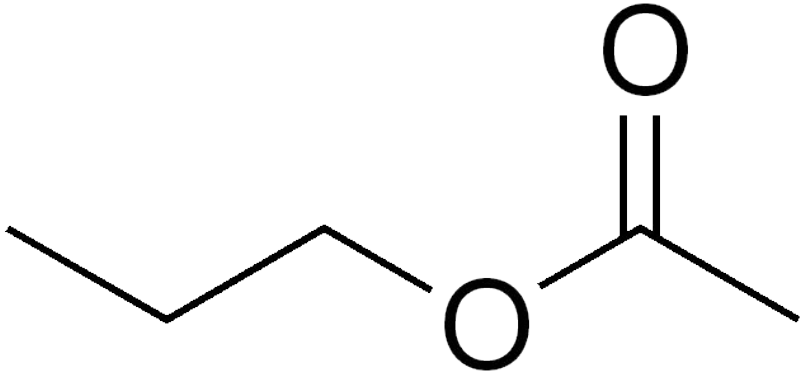


Exemplar Exam Question – Statement

1) Name the following ester:

Context: naming esters

Command:
simple answer

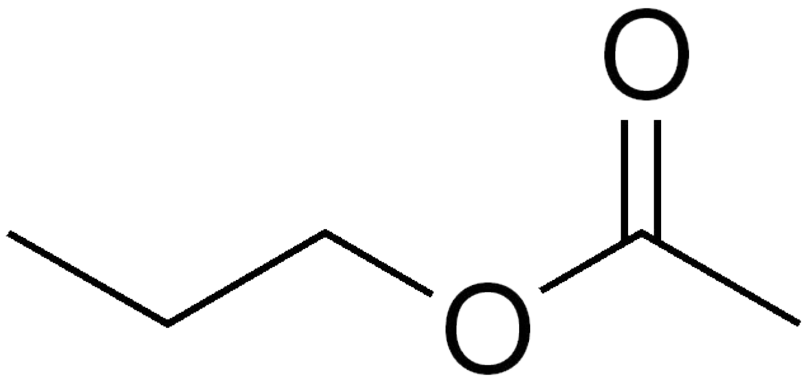


[1 mark]

Direction: what is the ester made of?

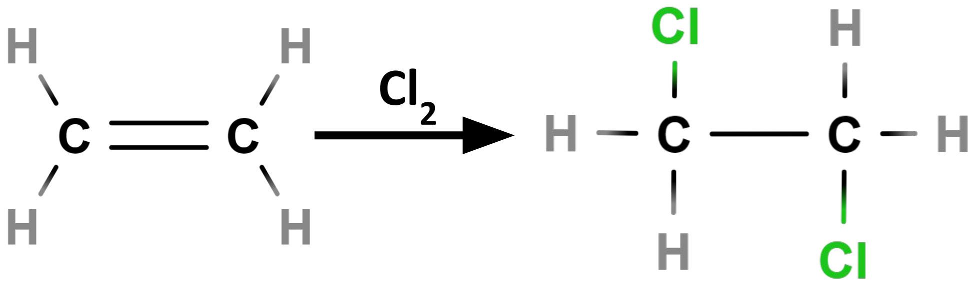
Exemplar Exam Question – Statement

1) Name the following ester:

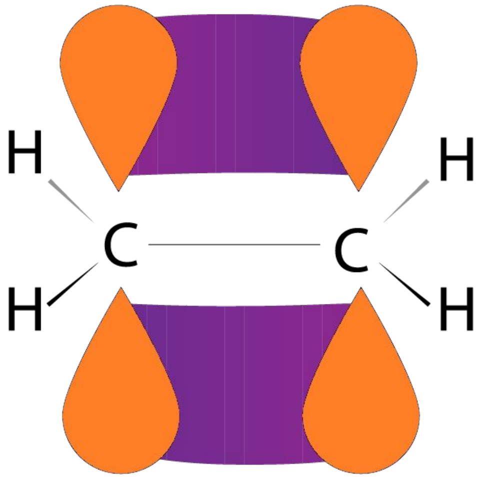


[1 mark]

Addition Reactions



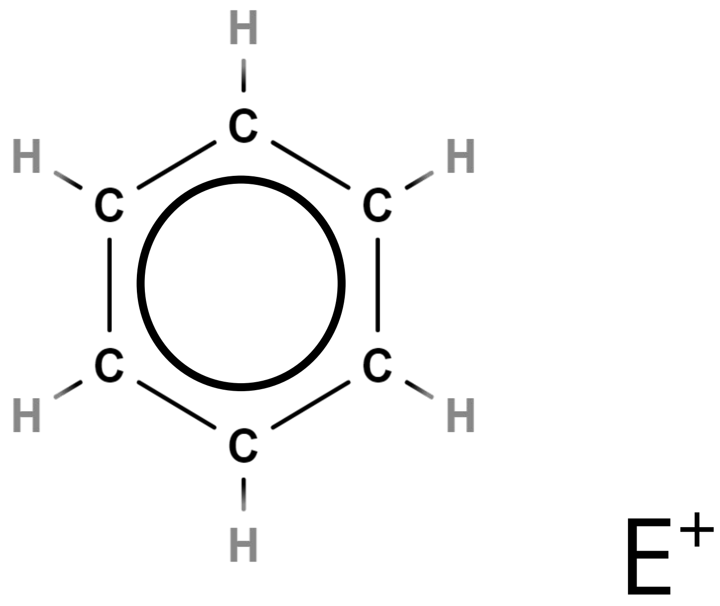
Addition of a **halogen** to the **carbon-carbon double bond** in an alkene



Benzene- Electrophilic Substitution

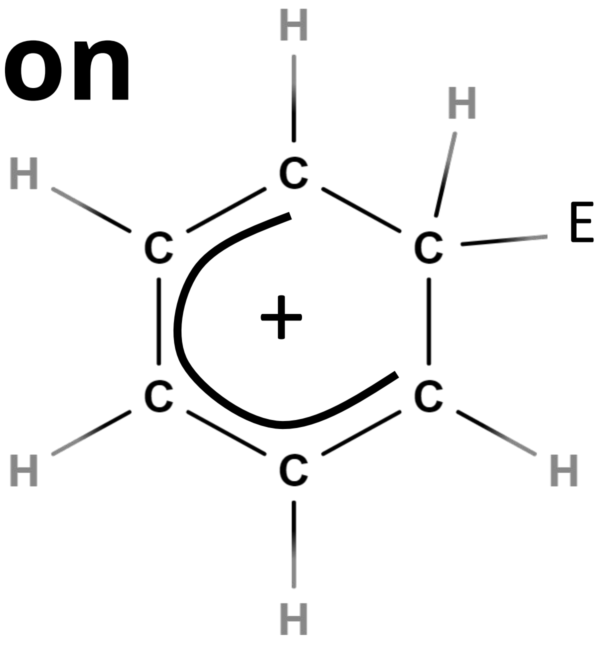
Benzene is unsaturated but doesn't undergo **addition reactions** due to the **stability** of its **delocalised system**

Instead **electrophilic substitution** occurs:

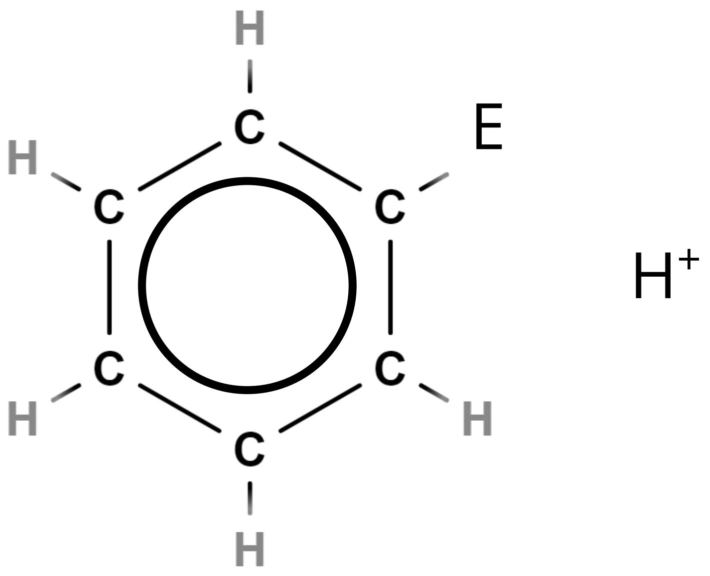


The electrophile accepts a **pair of π electrons** from the ring leading to the formation of a **covalent bond**: this is the slowest **rate-determining step** as it leads to the loss of the delocalisation stability

Benzene- Electrophilic Substitution



The final step is the **elimination of H$^+$** so that the **stable** delocalised electron system can be **restored**



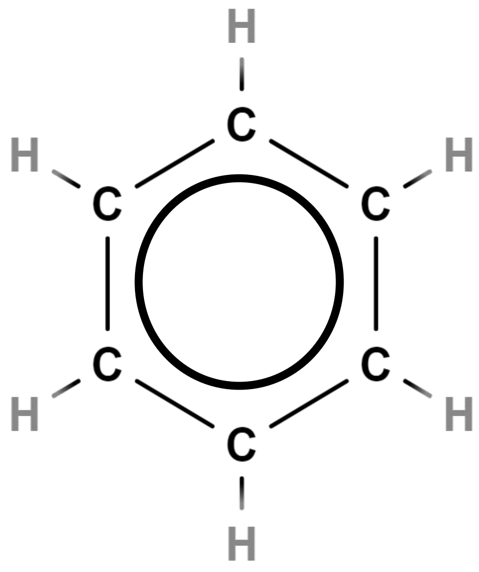
This step happens **rapidly**

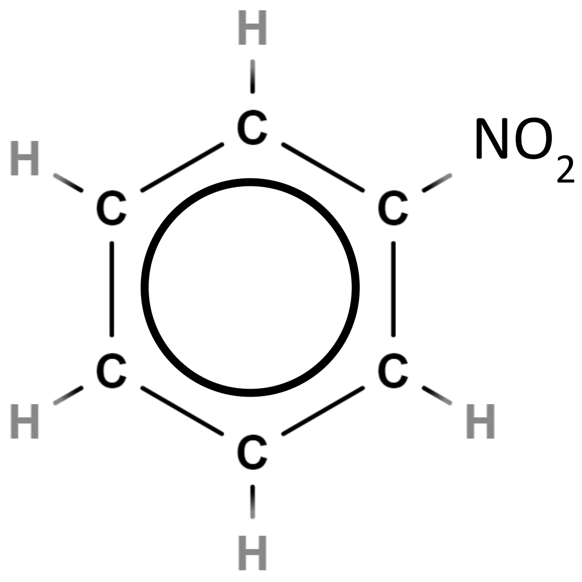
Substitution = addition + elimination

Benzene- Nitration

Nitration: the **electrophile** is NO_2^+ and is generated by reacting **nitric acid** with concentrated **sulphuric acid**

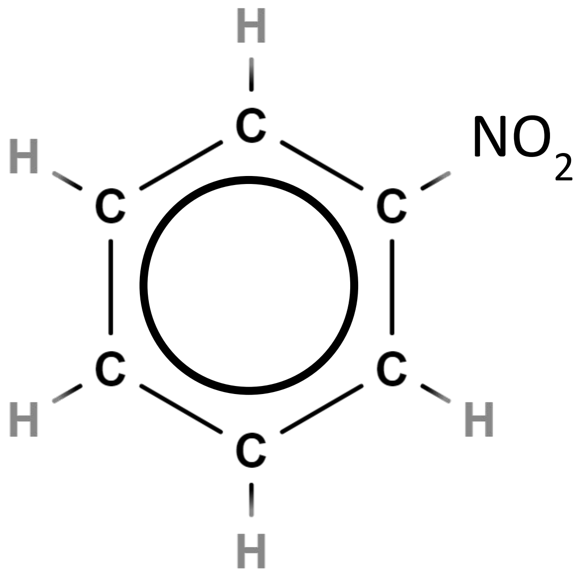
$H_2SO_4 + HNO_3 \square \mathbf{NO_2^+} + HSO_4^- + H_2O$





Benzene- Amine formation

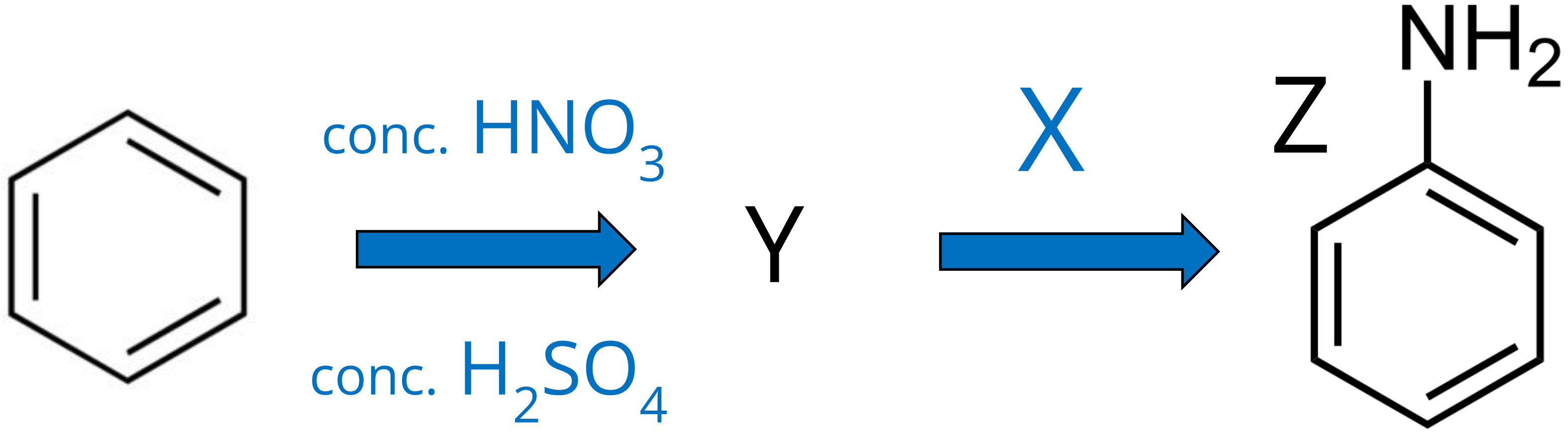
Nitrobenzene can then be **reduced** to produce an **amine** using **tin** and **conc. HCl**



Exemplar Exam Question – Short Answer

2) A synthetic route to form the product Z from benzene is shown below:

a) Identify species Y and draw its skeletal formula. **[2 marks]**



Command: simple answer

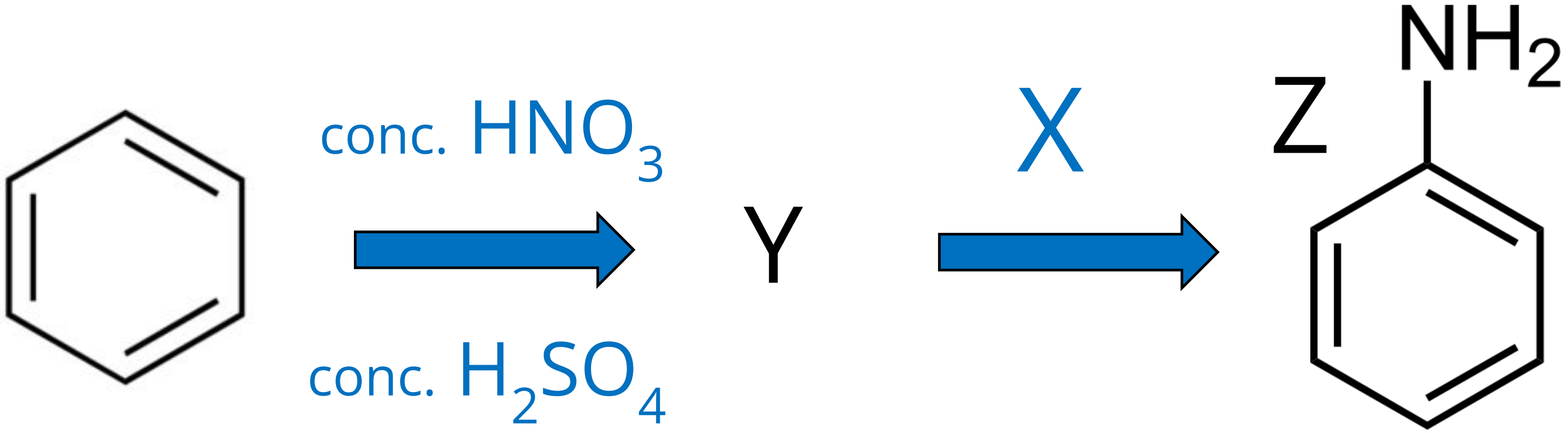
Direction: which reagents form which groups on benzene

Context: reactions of benzene

Exemplar Exam Question – Short Answer

2) A synthetic route to form the product Z from benzene is shown below:

b) Identify the conditions (X) needed to form Z from Y. **[2 marks]**



Command:
simple answer

Direction: which reagents form what groups on benzene

Context:
reactions of benzene

Exemplar Exam Question – Short Answer

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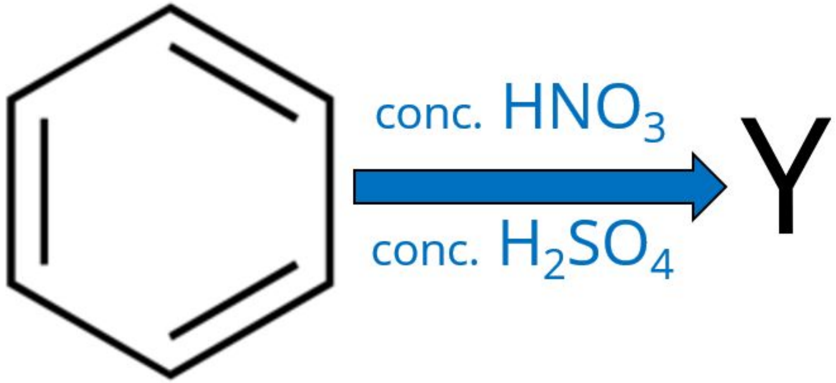
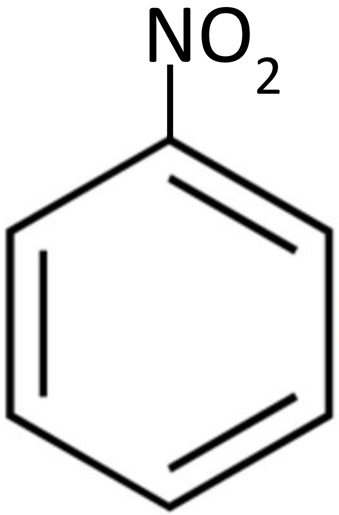


NO_2^+ electrophile formed- Nitration

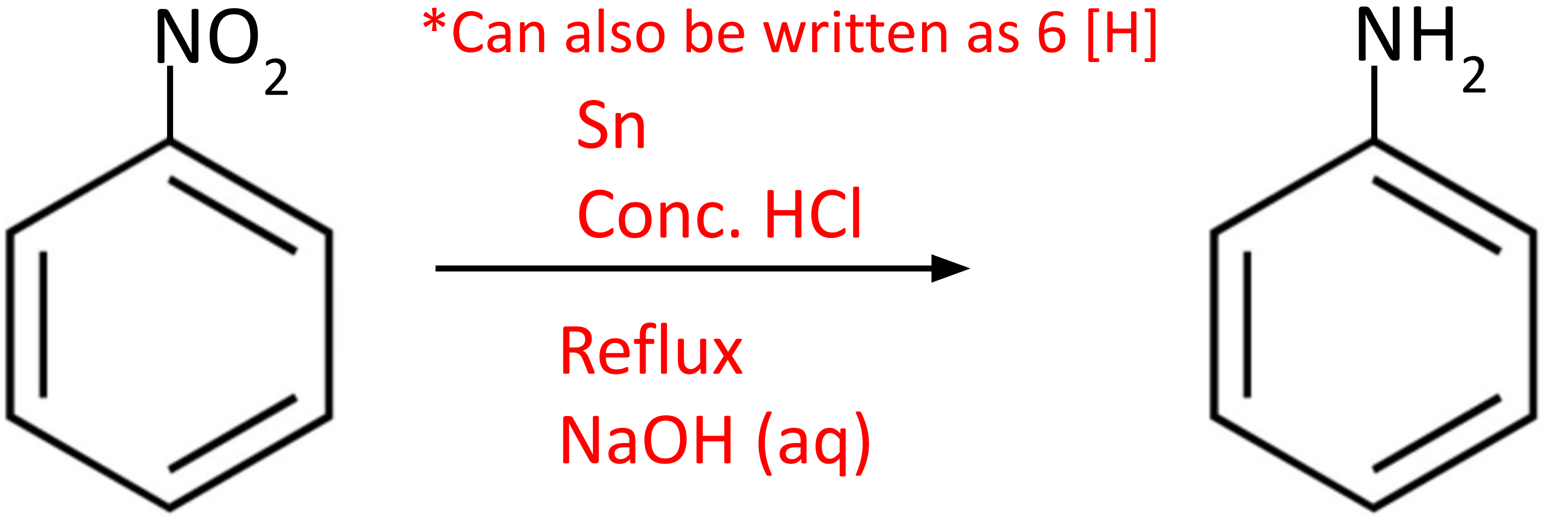


Nitrobenzene

Exemplar Exam Question – Short Answer

2) A synthetic route to form the product Z from benzene is shown below:

b) Identify the conditions (X) needed to form Z from Y. **[2 marks]**

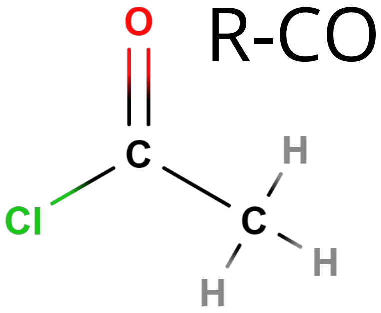


Benzene- Acylation (Friedel-Crafts)

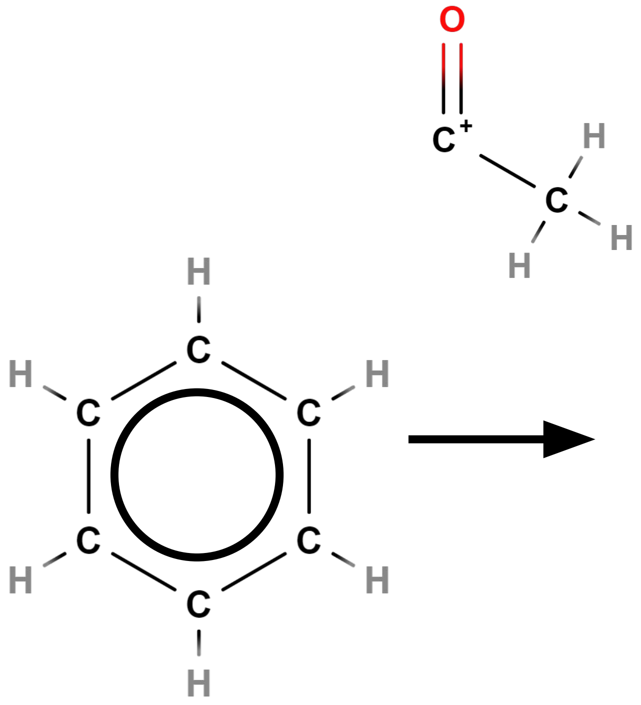
An **R-CO** group can be added to benzene in an **acylation reaction**

- R-CO$^+$ is generated from an **acyl chloride** and **AlCl$_3$**

$$\text{R-COCl} + \text{AlCl}_3 \longrightarrow \text{R-CO}^+ + \text{AlCl}_4^-$$



e.g. Ethanoyl chloride



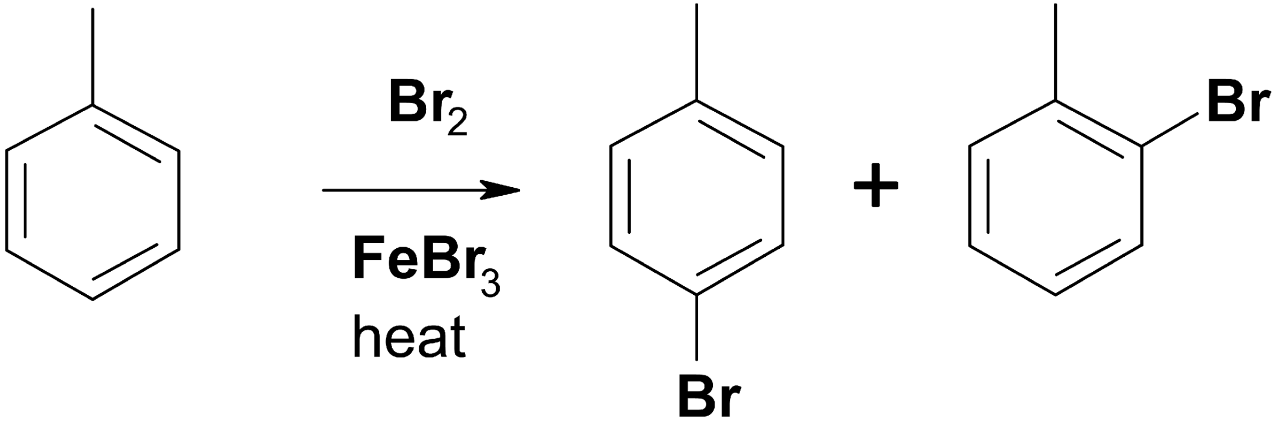
Not for

Benzene- Halogenation

Benzene doesn’t react **directly** with the halogens as the aromatic ring is **too stable… so how** do we **add a halogen** to an aromatic ring?

Using a **Halogen Carrier** (e.g. Iron)
- forms an **iron halide** *in situ*
- acts as a **catalyst**

- **Chlorination**: $AlCl_3/FeCl_3/Fe$ with Cl_2
- **Bromination**: $AlBr_3/FeBr_3/Fe$ with Br_2



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

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

Exemplar Exam Question – Short Answer

3) a) Draw a general mechanism for electrophilic substitution using benzene and an unspecified electrophile X. **[3 marks]**

Command:
simple drawing – mechanism

Direction: recall mechanism for electrophilic substitution

Context: electrophilic substitution of benzene

Exemplar Exam Question – Short Answer

3) b) Which of the following could be X?

Cl^- NO_2^+ NH_3 RCO^+ HBr

[2 marks]

Command:
simple answer – state possible answers

Direction: consider what is an electrophile

Context: electrophiles involved in electrophilic substitution

Exemplar Exam Question – Short Answer

3) c) Identify the conditions needed to form chlorobenzene from benzene.

[2 marks]

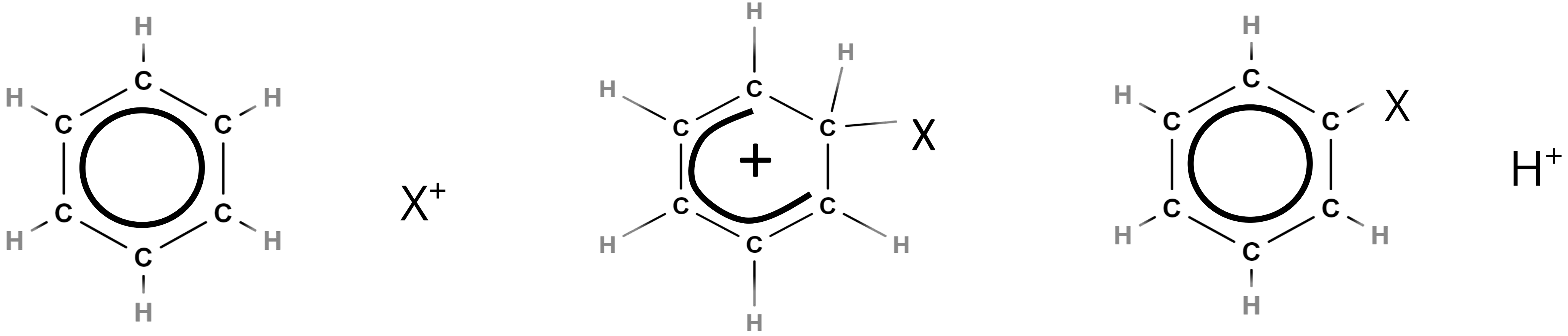
Command: recall reagents and conditions

Direction: consider what group is on chlorobenzene

Context: reagents and conditions of reactions involving benzene

Exemplar Exam Question – Short Answer

3) a) Draw a general mechanism for electrophilic substitution using benzene and an unspecified electrophile X. **[3 marks]**



Exemplar Exam Question – Short Answer

3) b) Which of the following could be X?

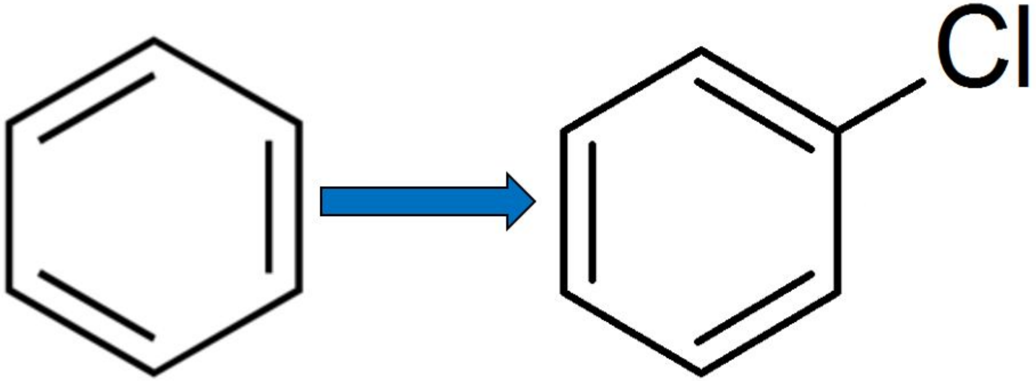
Cl^-	No
NO_2^+	Yes
NH_3	No
RCO^+	Yes
HBr	No

[2 marks]

Exemplar Exam Question – Short Answer

3) c) Identify the conditions needed to form chlorobenzene from benzene.

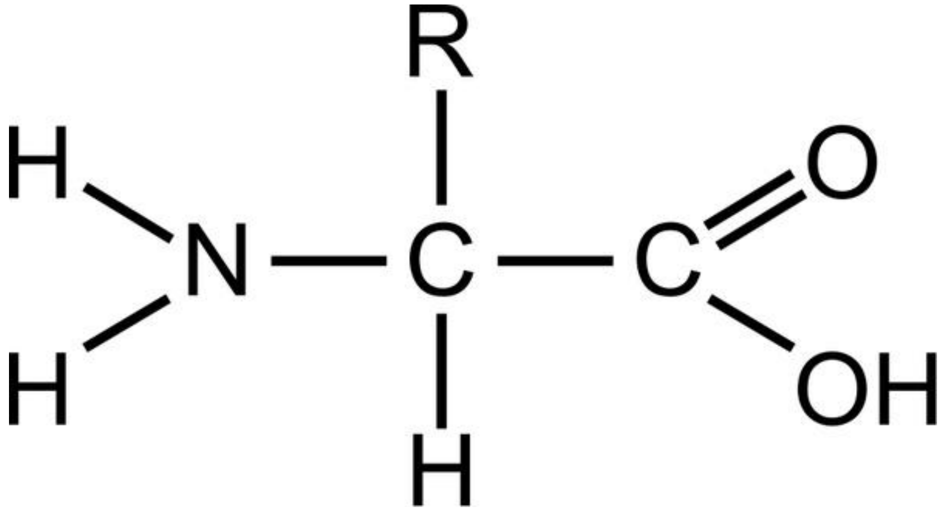
[2 marks]



Chlorination: $AlCl_3$ or $FeCl_3$ or Fe with Cl_2

Amino Acids

Amino acids are a **class of molecules** with **similar structures**



They all have:

- An **amine group**
- A **carboxylic acid** group
- An **R group**

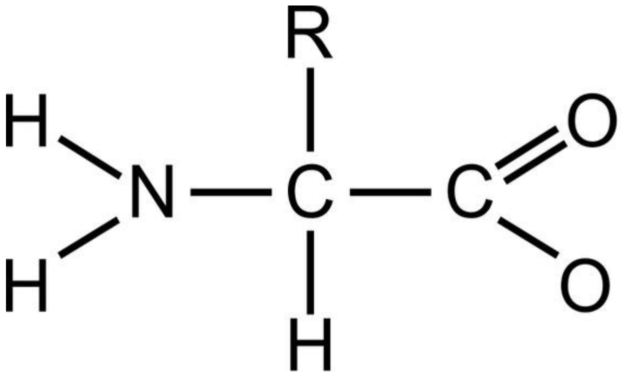
The **R group** determines the **chemical properties** of the **amino acid**

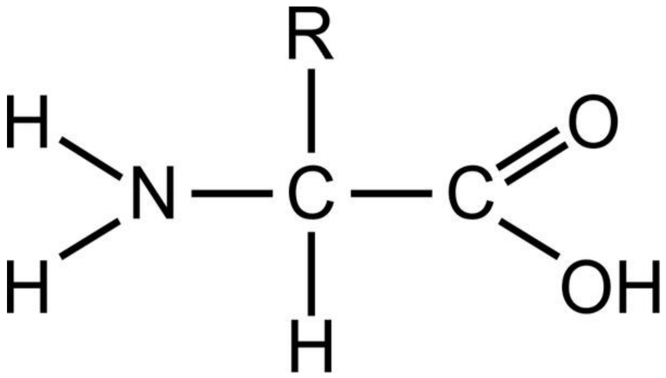
There are **20** different amino acids made using our DNA

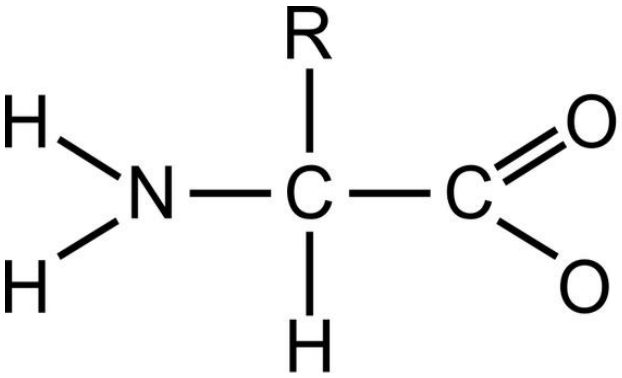
Amino Acids

Not for OCR
AQA does not need ‘isoelectric point’

Depending on the pH, an amino acid can exist as a positive ion, negative ion, or a zwitterion:





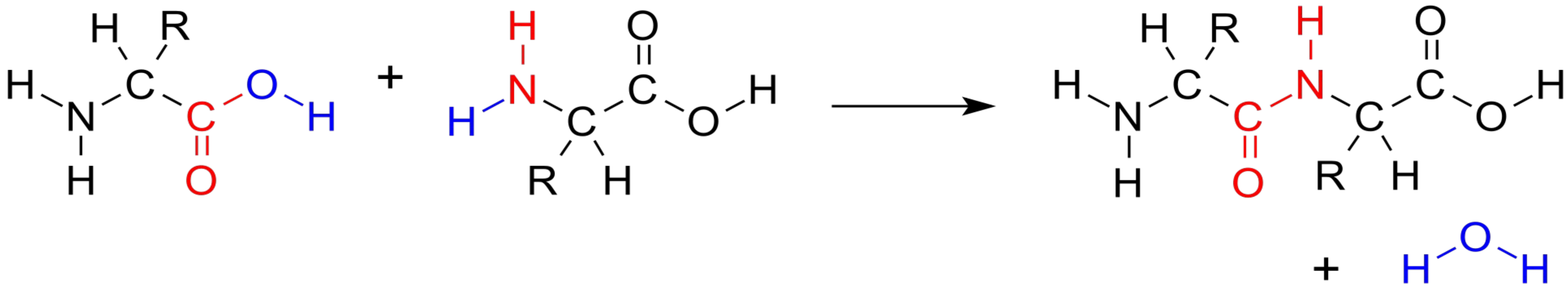


Amino Acids

Mechanism is AQA only

Although all amino acids have different chemical properties, they can all bond to form the **same structure**: the **polypeptide** or **polyamide**

A polypeptide is a **long chain of amino acids**, joined together by **amide/peptide bonds**



Exemplar Exam Question – Statement

4) The secondary and tertiary structure of a protein can be determined with x-ray crystallography. The first step is determining the sequence of polypeptides in the protein.

a) State the reaction that forms polypeptides. **[1 mark]**

Command:
simple answer

Direction: state a reaction type

Context:
Polypeptides

Exemplar Exam Question – Statement

4) The secondary and tertiary structure of a protein can be determined with x-ray crystallography. The first step is determining the sequence of polypeptides in the protein.

b) State the minimum overall charge of a polypeptide in an acidic solution.

[1 mark]

Command:
simple answer

Direction: consider relationship between pH and charge

Context:
polypeptides

Exemplar Exam Question – Statement

4) The secondary and tertiary structure of a protein can be determined with x-ray crystallography. The first step is determining the sequence of polypeptides in the protein.

a) State the reaction that forms polypeptides. **[1 mark]**

Condensation reaction

Exemplar Exam Question – Statement

4) The secondary and tertiary structure of a protein can be determined with x-ray crystallography. The first step is determining the sequence of polypeptides in the protein.

b) State the minimum overall charge of a polypeptide in an acidic solution.

[1 mark]

1+

MINI MOCK PAPER

Mini Mock Paper

1) Give a balanced equation for refluxing tin and conc. HCl, with nitrobenzene. You may use [H] to represent the reducing agent.

[2 marks]

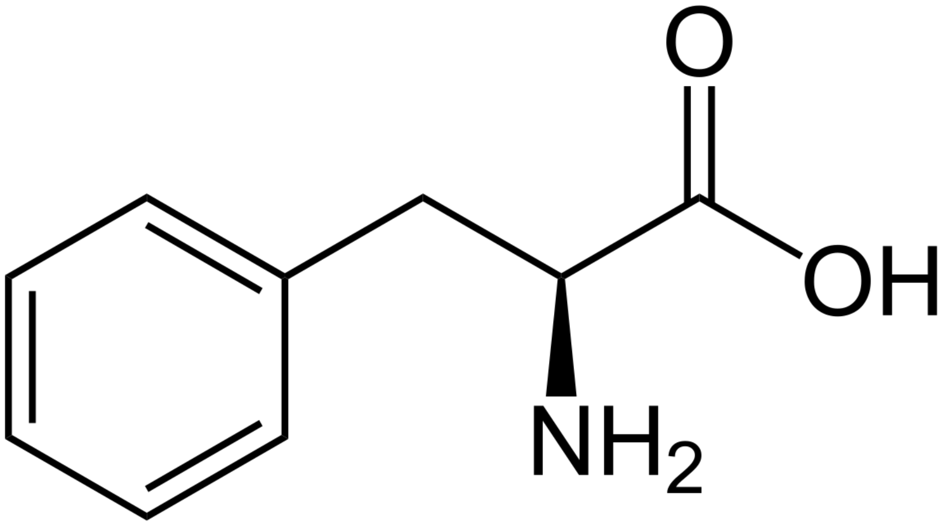
Mini Mock Paper

2) Describe the Kekulé model of benzene and explain why it is no longer considered accurate.

[3 marks]

Mini Mock Paper

3) The structure of phenylalanine is shown below. The isoelectric point of phenylalanine is pH 5.48.



(i) Draw the structure of phenylalanine at this pH.
(ii) What is this type of ion called?

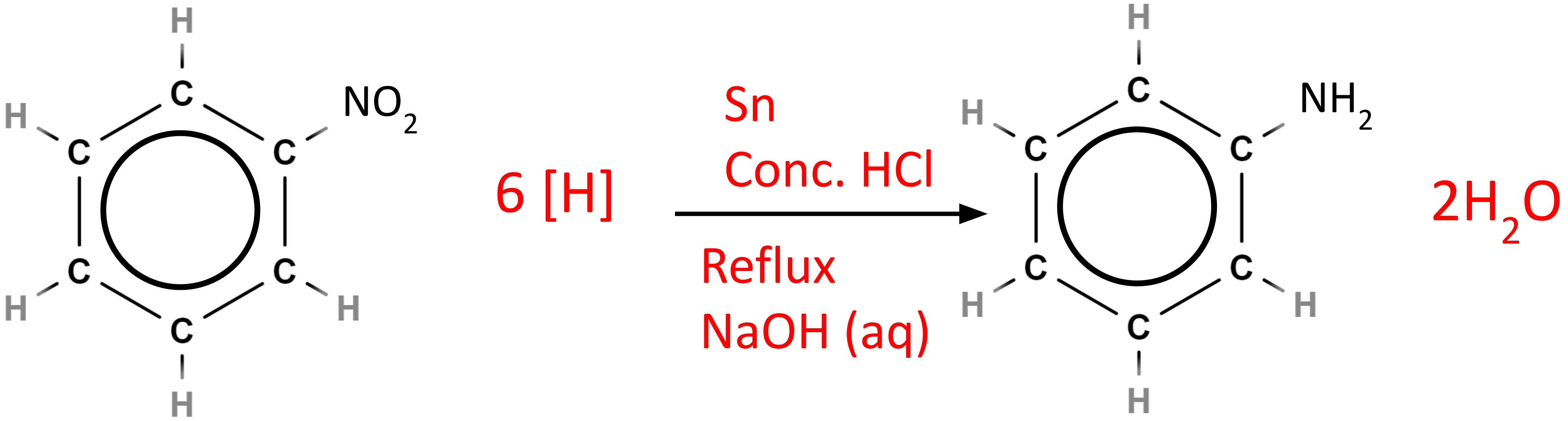
[3 marks]

MINI MOCK PAPER ANSWERS

Mini Mock Paper

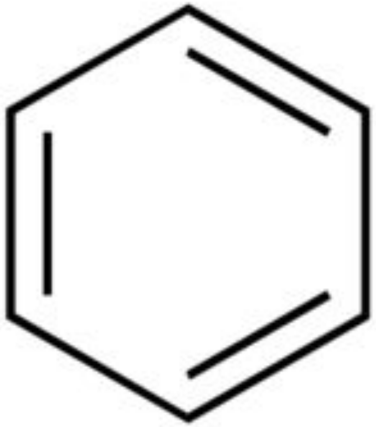
1) Give a balanced equation for refluxing tin and conc. HCl, with nitrobenzene. You may use [H] to represent the reducing agent.

[2 marks]



Mini Mock Paper

2) Describe the Kekulé model of benzene and explain why it is no longer considered accurate. **[3 marks]**



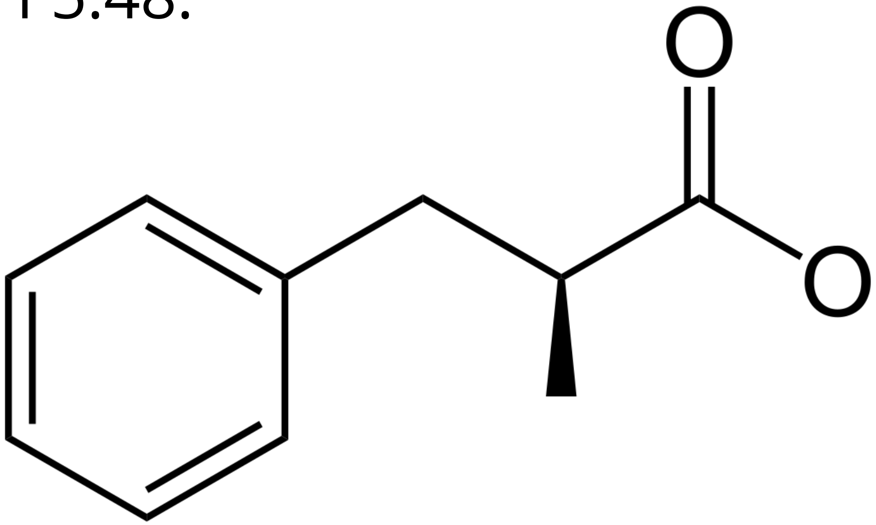
Kekulé Model: alternating single and double bonds

Incorrect due to the following:

- Benzene does not undergo addition reactions easily
- Benzene is much more stable than we would predict from alternating double and single bonds between C (reference to bond enthalpies)
- All 6 bond lengths are equal (reference to x-ray diffraction)

Mini Mock Paper

3) The structure of phenylalanine is shown below. The isoelectric point of phenylalanine is pH 5.48.



(i) Draw the structure of phenylalanine at this pH

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[3 marks]