

29.2 Characteristic organic reactions

Name: _____ Class: _____ Date: _____

Total: 21 marks

KEY WORDS electrophilic substitution

- characteristic organic reactions

- addition–elimination

- free radicals

- electrophiles

Objective

Build the skills to answer exam questions on **characteristic organic reactions**

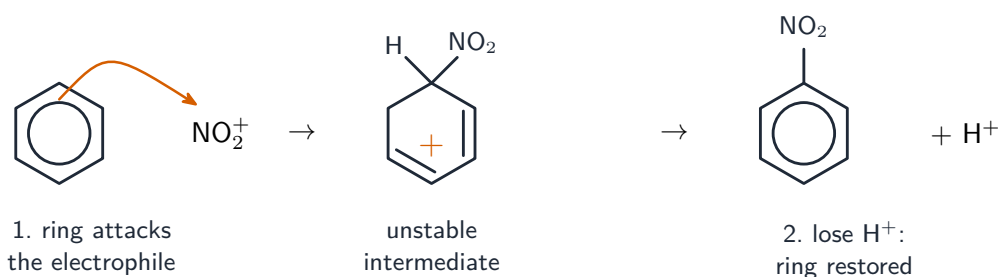
– classifying a reaction by its type and the kind of reagent involved.

You must be able to:

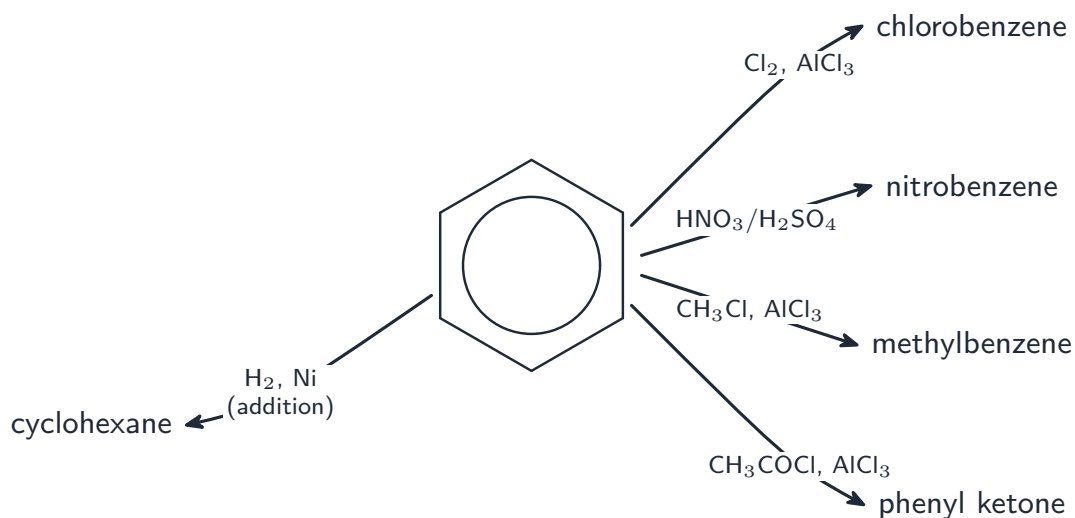
- classify reactions as addition, substitution, elimination, hydrolysis, condensation, oxidation, reduction or polymerisation
- classify reagents as **electrophiles**, **nucleophiles** or **free radicals**
- describe the two new mechanism types: **electrophilic substitution** and **addition–elimination**

1 Key knowledge and worked examples

■ Naming the reaction type



Electrophilic substitution: an electrophile replaces a ring hydrogen – the characteristic reaction of benzene



Characteristic reactions of the benzene ring

- **electrophilic substitution** – an electrophile replaces an H on a benzene ring (e.g. nitration).
- **nucleophilic substitution** – a nucleophile replaces a leaving group (e.g. OH^- + halogenoalkane).
- **addition** – a π bond opens and two groups add on (e.g. Br_2 + alkene).
- **addition–elimination** – a group adds, then a small molecule leaves (e.g. 2,4-DNPH, acyl chlorides).

Reagent types: electrophile = electron-pair **acceptor**; nucleophile = electron-pair **donor**; radical = species with an unpaired electron.

2 Practice

2.1 State what is meant by an **electrophile**. [1]

2.2 Classify the reaction of bromine with ethene (an alkene). [1]

3 Exam-style questions

3.1 The reaction of OH^- with bromoethane is best classified as: [1]

- ☐ A electrophilic addition
B nucleophilic substitution
C electrophilic substitution
D free-radical substitution

3.2 Which species is a nucleophile? [1]

- ☐ A NO_2^+
B H^+
C $:\text{NH}_3$
D $\text{Cl}^\bullet$

3.3 For each reaction, name the **type** and the **reagent class**: [3]

- (a) $\text{benzene} + \text{NO}_2^+ \rightarrow \text{nitrobenzene} + \text{H}^+$
(b) $\text{ethene} + \text{Br}_2 \rightarrow 1,2\text{-dibromoethane}$
(c) $\text{an ester} + \text{water} \rightarrow \text{a carboxylic acid} + \text{an alcohol}$

3.4 Explain why benzene undergoes **substitution** rather than **addition**, unlike an alkene. [2]

3.5 Four reactions of propene and its derivatives are shown.

- **I** $\text{CH}_3\text{CH}=\text{CH}_2 + \text{Br}_2 \rightarrow \text{CH}_3\text{CHBrCH}_2\text{Br}$
- **II** $\text{CH}_3\text{CHBrCH}_3 + \text{KOH}(\text{aq}) \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_3 + \text{KBr}$
- **III** $\text{CH}_3\text{CHBrCH}_3 + \text{KOH}$ in ethanol $\rightarrow \text{CH}_3\text{CH}=\text{CH}_2 + \text{KBr} + \text{H}_2\text{O}$
- **IV** $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3 + [\text{O}] \rightarrow \text{CH}_3\text{COCH}_3 + \text{H}_2\text{O}$

(a) Classify each reaction by type.

[4]

(b) For **I**, name the attacking species and explain how a non-polar bromine molecule comes to attack an alkene.

[3]

(c) Reactions **II** and **III** use the same reagent on the same compound but give different products. Explain what decides which happens.

[2]

(d) Name a suitable oxidising agent for **IV**, and state what you would see. Explain why the product cannot be oxidised further.

[3]

Solutions

Each answer shows the steps, then the **result**.

2.1

- an electron-pair acceptor / a species that is attracted to a region of high electron density

2.2

- electrophilic addition

3.1 B

- OH^- is a nucleophile and it replaces the bromine – nucleophilic substitution

3.2 C

- :NH_3 has a lone pair to donate – a nucleophile

3.3

(a)

- electrophilic substitution; electrophile

(b)

- (electrophilic) addition; electrophile

(c)

- hydrolysis (substitution); water/nucleophile

3.4

- benzene's delocalised π system is very stable; substitution keeps the stable ring intact, whereas addition would destroy the delocalisation, so substitution is favoured

3.5

(a)

- **I** electrophilic addition; **II** nucleophilic substitution; **III** elimination; **IV** oxidation

(b)

- The **electrophile** is bromine, Br_2 , acting as $\text{Br}^{\delta+}-\text{Br}^{\delta-}$. The high electron density of the π bond repels the electrons in the approaching Br_2 , inducing a dipole; the now $\delta+$ bromine atom is attacked by the π electrons

(c)

- The **solvent and conditions**: aqueous KOH favours substitution, giving the alcohol; hot KOH in ethanol favours elimination, giving the alkene

(d)

- Acidified potassium dichromate(VI), $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$; the solution turns from orange to green as $\text{Cr}_2\text{O}_7^{2-}$ is reduced to Cr^{3+} . Propanone is a **ketone** – its carbonyl carbon carries no hydrogen, so further oxidation would need a C–C bond to break, which this reagent cannot do