1

Reactions

2. Elimination

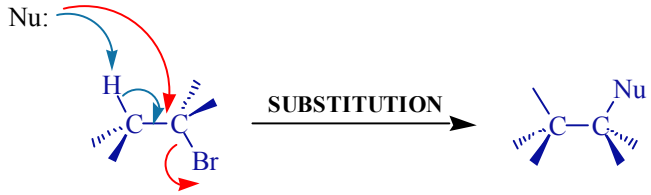
- Alkyl halide is treated with a base

2

Reactions

2. Elimination

- Often competes with nucleophilic substitution

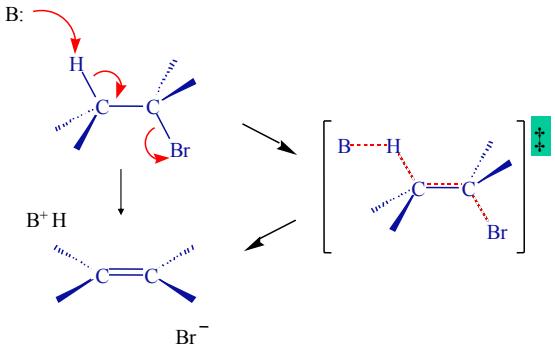


3

Elimination

Mechanism

- Bimolecular



4

E2

Kinetics

- Rate determining step involves both reactants

rate = k [base] [R-X]

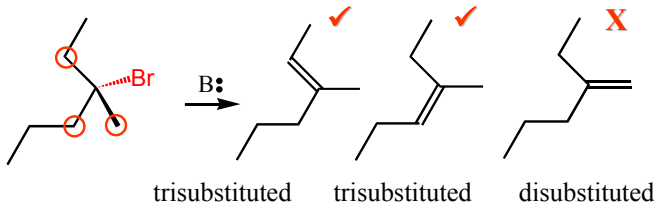
- Second order kinetics

E2 = **E**limination, **2**nd order

E2

Zaitsev's Rule

- In some cases a number of elimination products are possible:



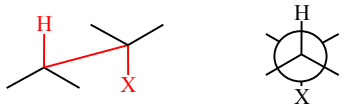
- the most substituted products dominate

E2

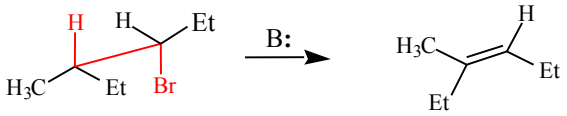
Stereochemistry

- Occurs in anti-periplanar geometry

Anti Periplanar



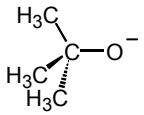
- ∴ Only one isomer is formed



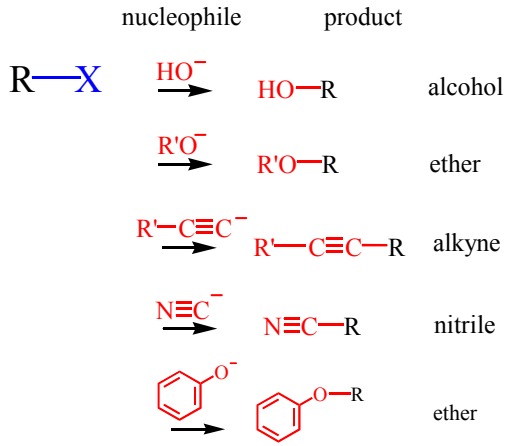
S_N2 and E2

- S_N2 favoured with
  - Low temp
  - 1º substrates
  - good n'phile *eg*. Br^-

- E2 favoured with
  - High temp
  - 3º substrates
  - Strong/bulky base

tert-butoxide 

S_N2 in synthesis



9

Nucleophilic Substitution

Alternative Mechanism

- Called S_N1
- poor nucleophile, 3° substrate
- different kinetics and stereochemistry are observed

rate = k [R-Br]

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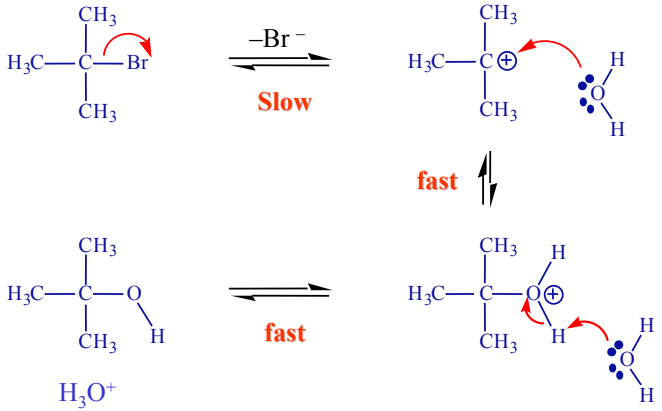
S_N1 Mechanism

Mechanism



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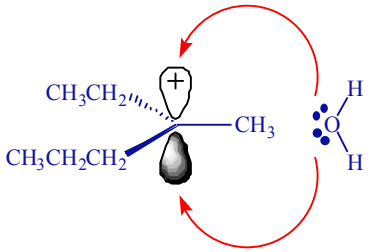
S_N1 Mechanism

Stereochemistry

- carbocation intermediate



- Mixture of enantiomers formed

12

Elimination

Alternative Mechanism

- Called **E1**
- poor base, 3° substrate
- First order kinetics
- mechanism again involves carbocation

rate = k [R-Br]

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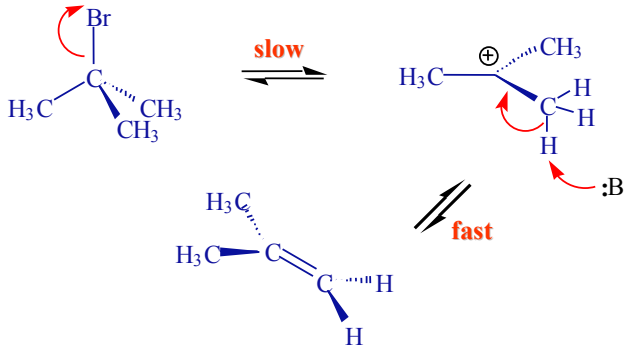
E1 Mechanism

Mechanism



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E1

Stereochemistry

- no requirement for anti-periplanar geometry
  - Substrate can lose a proton from any neighbouring position

Zaitsev's Rule

- most substituted alkene will dominate

15

SN1 and E1

- Difficult to differentiate
  - Both involve carbocation intermediate

In general:
↓Temp = sub
↑Temp = elim

- S_N1 and E1 much less useful than S_N2 and E2

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Organic Chemistry

Alkanes

Alkenes

Alkynes

Benzene

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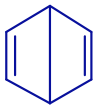
Structure

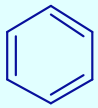
The Kekule Proposal

- possible constitutional isomers for benzene (C_6H_6)

Ladenburg



Dewar



Kekule

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Stability

Stability of Benzene

- unusually high stability
  - compare with alkenes

Br_2 → **NO REACTION**

H_3O^+ → **NO REACTION**

HCl → **NO REACTION**

WHY? - Resonance and Aromaticity

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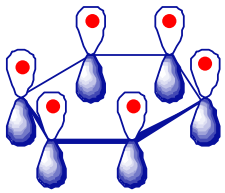
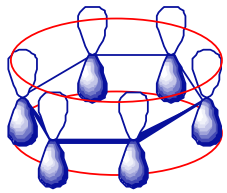
Structure

Resonance theory of benzene

- All bonds are equivalent!
- π electrons are delocalised around the ring





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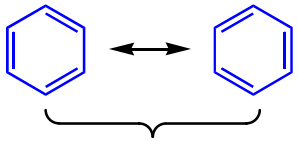
Resonance Theory

1.Resonance forms are imaginary

- benzene has a single **hybrid** structure which combines the characteristics of both **resonance** forms

Resonance forms



Hybrid structure

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Resonance Theory

2. Resonance forms only differ in the position of π electrons
3. neither the position or hybridisation of the atoms change
4. The more resonance forms there are, the more stable the molecule.

We call these molecules resonance stabilised

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Aromaticity

- special characteristic of certain resonance stabilised systems

Requirements

- cyclic
- planar
- conjugated
  - overlapping p orbitals between all atoms
- (4n + 2) π electrons

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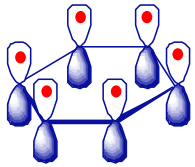
Aromaticity

Example 1: Benzene

- cyclic ✓
- planar ✓
- conjugated ✓
- 6 π electrons ✓



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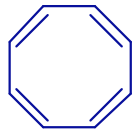
Aromaticity

Other Examples?

cyclic ✓
planar ✓
conjugated ✓
6π electrons X



cyclic ✓
planar ✓
conjugated ✓
6π electrons X

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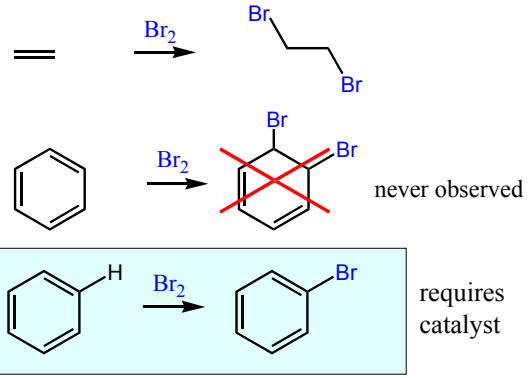
Reactions

Electrophilic Aromatic Substitution

Benzene undergoes substitution NOT addition



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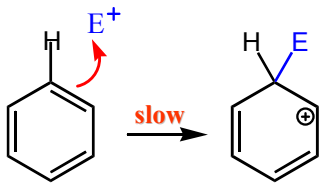
Reactions

Electrophilic Aromatic Substitution

Mechanism

- Step 1



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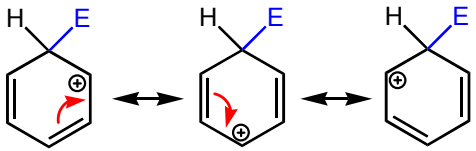
Halogenation

The Intermediate Cation

- stabilised by **resonance**



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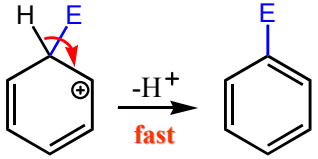
Reactions

Electrophilic Aromatic Substitution

Mechanism

- Step 2



- Only variation is the Electrophile

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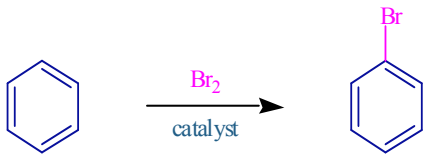
Reactions

1. Halogenation

Bromination

- benzene is treated with bromine and a catalyst (usually $FeBr_3$)



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Halogenation

Bromination

- The catalyst 'activates' the electrophile (Br_2)

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

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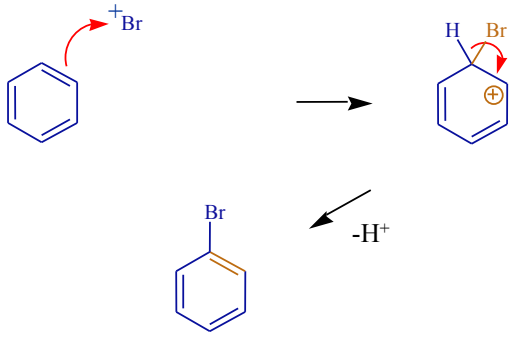
Halogenation

Mechanism



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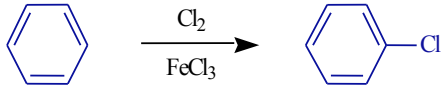
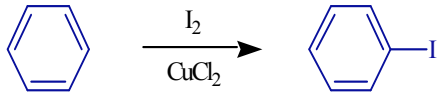
Halogenation

Other Halogenations

Chlorine



Iodine



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Reactions

2. Nitration

- the electrophile is generated by reacting nitric acid with sulfuric acid

$$HNO_3 + H_2SO_4 \longrightarrow H_2O + HSO_4^- + NO_2^+$$

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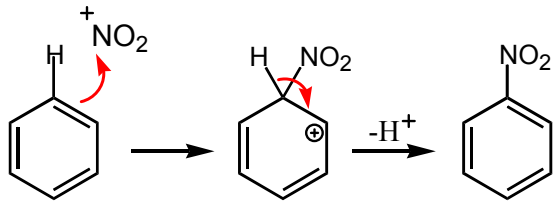
Reactions

mechanism



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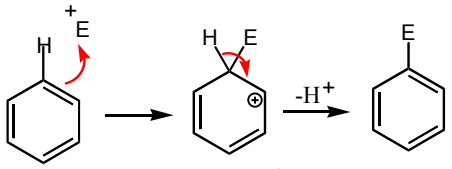
Electrophilic Aromatic substitution

Mechanism



resonance stabilised
ARENIUM ION

Nitration

$$HNO_3 + H_2SO_4 \longrightarrow H_2O + HSO_4^- + NO_2^+$$

Nitronium ion

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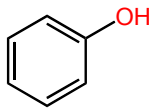
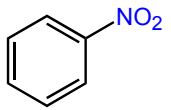
Substituted Benzenes

Substituent Effect on Reactivity



phenol is 1000 x more reactive than benzene



nitrobenzene is 20,000,000 x less reactive than benzene

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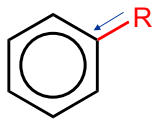
Substituent Effects

1. Ring Activating Substituents

- donate electrons to the ring
  - Best activators have lone pairs. eg Phenol
  - Stabilises the arenium ion ∴ it forms more readily
  - Faster reaction



R =	NH_2	lone pair
	NR_2	lone pair
	OH	lone pair
	OR	lone pair
	R	inductive

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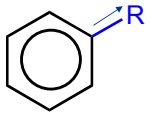
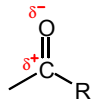
Substituent Effects

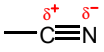
2. Ring Deactivating

- withdraw electrons from the ring
  - destabilise the arenium ion
  - Slower reaction

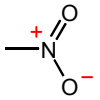




carbonyl containing



nitrile



nitro

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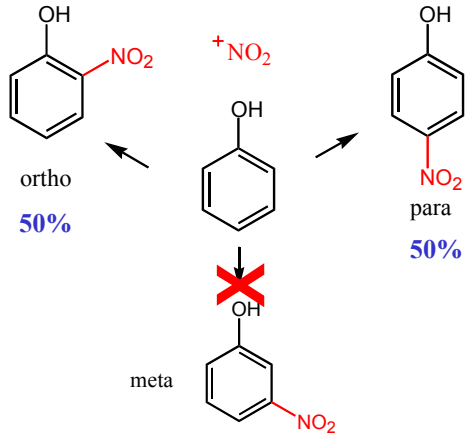
Substituent Effects

Directing

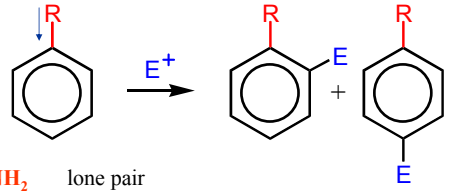


40

Substituent Effects

Ring Activators

- Direct to **ortho** and **para** positions
  - Lone pairs allow extra resonance structure



R =	NH_2	lone pair
	NR_2	lone pair
	OH	lone pair
	OR	lone pair
	R	inductive

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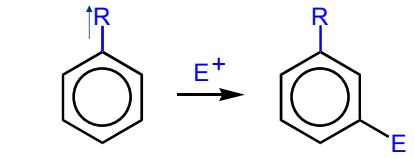
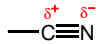
Substituent Effects

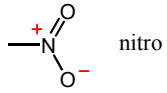
Ring Deactivators

- Direct to **meta** position
  - ortho and para are destabilised





nitrile



nitro

carbonyl containing

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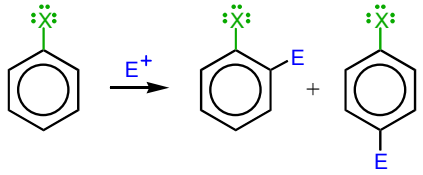
Substituent Effects

Halogens

- special case
- electron withdrawing
  - electronegative
- electron donating
  - lone pairs

Deactivating
Ortho para directing



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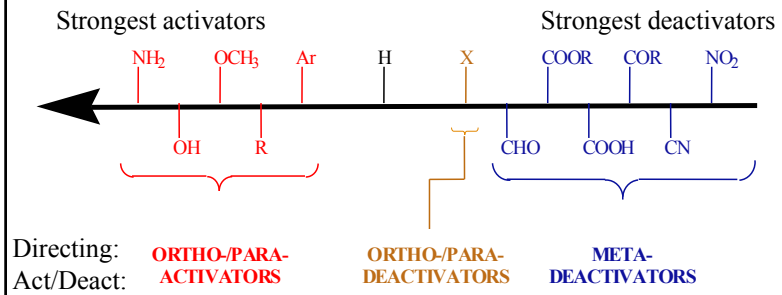
Substitent Effects

Summary



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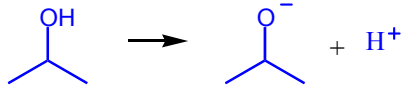
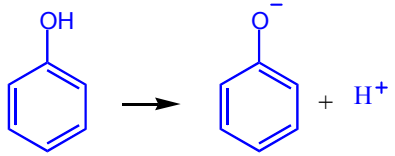
Phenol

Reactions

1. Acid



pK_a = 18 very poor acid



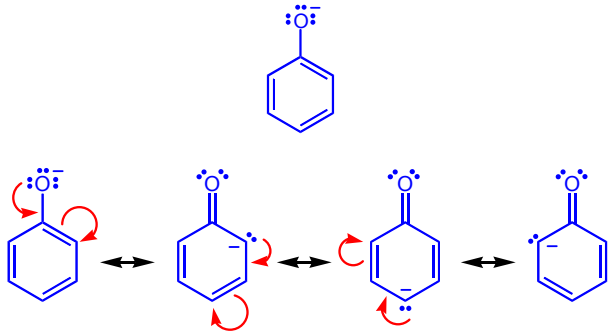
pK_a = 10 much better acid. Why?

45

Phenol

Acid

Conjugate base is RESONANCE stabilised



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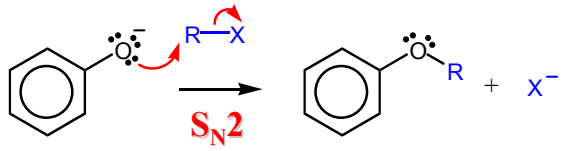
Phenol

Reactions

2. Nucleophile



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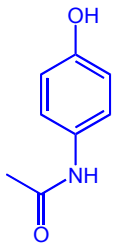
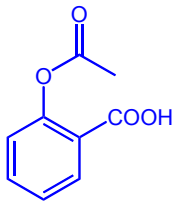
Phenol

Analgesics



PARACETAMOL



ASPIRIN