

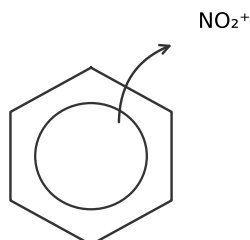
Solutions

Original marking guidance: M1 method, A1 accuracy, B1 explanation.

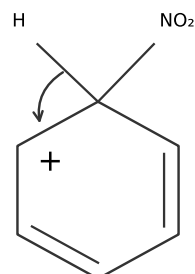
2.1

Nitration mechanism after NO_2^+ generation; curly arrows show electron pairs

1 Ring electron pair attacks

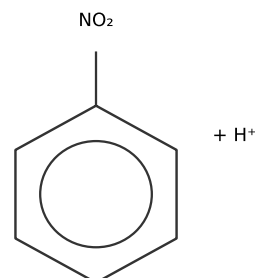


2 Positive intermediate



C-H bond pair restores ring

3 Nitrobenzene + H^+



B1 ring attack arrow; B1 intermediate with H and NO_2 on the same carbon and positive charge; B1 C-H pair returning to ring; B1 nitrobenzene and H^+ .

2.2 Concentrated sulfuric acid; HSO_4^- accepts H^+ to regenerate H_2SO_4 .

2.3 $\text{C}_2\text{H}_5\text{Cl} + \text{AlCl}_3 \rightarrow \text{C}_2\text{H}_5^+ + \text{AlCl}_4^-$; $\text{AlCl}_4^- + \text{H}^+ \rightarrow \text{AlCl}_3 + \text{HCl}$.

3.1 $\text{CH}_3\text{COCl} + \text{AlCl}_3 \rightarrow \text{CH}_3\text{CO}^+ + \text{AlCl}_4^-$. $\text{C}_6\text{H}_6 + \text{CH}_3\text{COCl} \rightarrow \text{C}_6\text{H}_5\text{COCH}_3 + \text{HCl}$, phenylethanone.

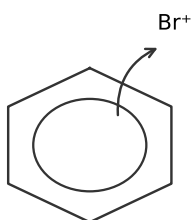
3.2 Oxygen lone-pair interaction increases ring electron density, easing electrophile attack. $\text{C}_6\text{H}_5\text{OH} + 3\text{Br}_2 \rightarrow \text{C}_6\text{H}_2\text{Br}_3\text{OH} + 3\text{HBr}$.

3.3 The first arrow must start at the ring electron pair and end at the electrophile. The second must start at the C-H bond pair and end at the ring bond as H^+ leaves.

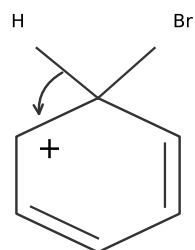
3.4

Bromination: simple electrophile model

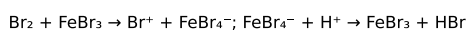
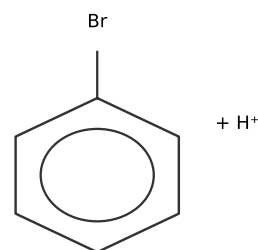
1 Ring pair attacks E^+



2 C-H pair restores ring



3 Bromobenzene

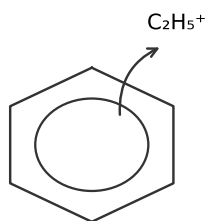


B1 electrophile generation; B1 ring electron-pair attack; B1 positive intermediate with H and incoming group on one carbon; B1 C-H bond arrow restoring ring; B1 correct aromatic product; B1 catalyst regeneration.

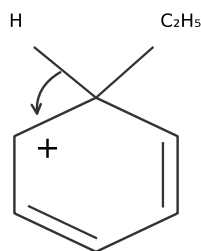
3.5

Alkylation: simple electrophile model

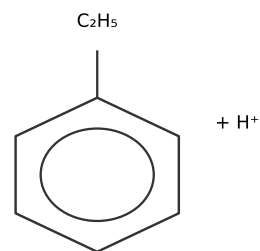
1 Ring pair attacks E⁺



2 C-H pair restores ring



3 Ethylbenzene

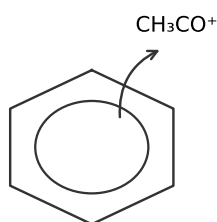


B1 electrophile generation; B1 ring electron-pair attack; B1 positive intermediate with H and incoming group on one carbon; B1 C-H bond arrow restoring ring; B1 correct aromatic product; B1 catalyst regeneration.

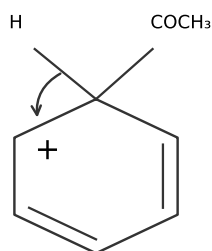
3.6

Acylation: simple electrophile model

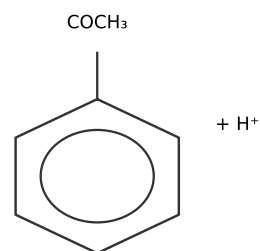
1 Ring pair attacks E⁺



2 C-H pair restores ring



3 Phenylethanone



B1 electrophile generation; B1 ring electron-pair attack; B1 positive intermediate with H and incoming group on one carbon; B1 C-H bond arrow restoring ring; B1 correct aromatic product; B1 catalyst regeneration.