11.4 Arenes

Set A **Answer key**

A From the lesson

13 MARKS

1 **(a)** Br_2, anhydrous $FeBr_3$, room temperature, dark [1]

(b) CH_3CH_2Cl, anhydrous $AlCl_3$, room temperature [1]

2 $Br_2 + FeBr_3 \rightarrow Br^+ + FeBr_4^-$ [1]

3 **(a)** Br_2, anhydrous $FeBr_3$, room temperature, in the dark [1]
Products: 2- and 4-bromomethylbenzene [1]

(b) Br_2, UV light [1]
Product: (bromomethyl)benzene, $C_6H_5CH_2Br$ [1]

4 Substitution keeps the delocalised π system and its extra stability: addition would destroy it. [1]

5 NO_2^+ [1]
$HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$ [1]

6 $-CH_3$ is electron-donating: it increases the ring's electron density [1]
and stabilises the carbocation intermediate. [1]

7 It has no benzylic H. [1]

B Practice

23 MARKS

8 **B** electrophilic substitution [1]
The reaction involves a Cl substituting for one of the H in benzene. Benzene is nucleophilic due to the π electron cloud with high electron density. Hence, benzene attracts electrophilic reagents.

9 **B** 3 and 4 [1]

1 Benzene has a simple molecular structure and does not conduct electricity.

2 Benzene undergoes substitution reactions easily as a result of its resonance stability.

3 The bond order of all C–C bonds in benzene is 1.5, due to resonance, which arises from the continuous overlap of unhybridised p orbitals.

4 Hydrogenation of benzene and of hypothetical cyclohexa-1,3,5-triene gives the same product, cyclohexane. Benzene is more stable than cyclohexa-1,3,5-triene due to resonance, so it exists at a lower energy level, resulting in a less exothermic enthalpy of hydrogenation.

10 **C** phenylamine, ethylbenzene, benzaldehyde [1]

Electron-donating groups increase the electron density of the benzene ring and are said to activate the ring. The more electron-rich the benzene ring, the more nucleophilic the ring, and hence the lower the reaction temperature.

Electron-donating ability: $-NH_2 > -C_2H_5 > -H > -CHO > -CO_2H$

11 **(a)**

(i) reagent: Cl_2, anhydrous $FeCl_3$, benzene. Condition: room temperature [1]

(ii) reagent: Br_2, anhydrous $FeBr_3$, benzene. Condition: room temperature [1]

(iii) reagent: concentrated HNO_3, concentrated H_2SO_4, benzene. Condition: temperature below 55 °C [1]

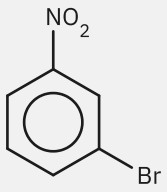
(b)

NO_2^+ [1]

(c)

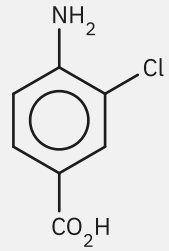
[1]

(i)



[1]

(ii)



12 **(a)**

Test: to separate samples of each compound, add hot $KMnO_4$ in dilute H_2SO_4. Observations: for benzene, the purple solution remains. For methylbenzene, the purple solution is decolourised, and a white precipitate is observed on cooling. [1]

Equation: $C_6H_5CH_3 + 3[O] \rightarrow C_6H_5CO_2H + H_2O$ [1]

(b)

Test: to separate samples of each compound, add Br_2 with $FeBr_3$, in the dark. Observations: for cyclohexane, no colour change is observed and no gas is evolved. For benzene, reddish brown Br_2 is decolourised, with the evolution of white fumes of HBr. [1]

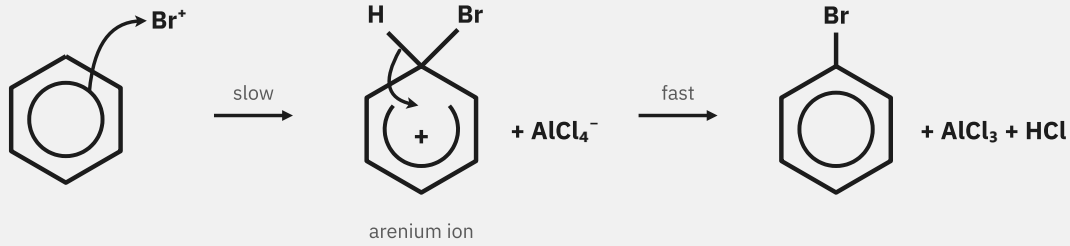
Equation: $C_6H_6 + Br_2 \rightarrow C_6H_5Br + HBr$ ($FeBr_3$) [1]

13 **(a)**

Br is less electronegative than Cl, hence will react with $AlCl_3$ to form the electrophile Br^+, which undergoes electrophilic substitution with benzene. [1]

(b)

Electrophilic substitution. $BrCl + AlCl_3 \rightleftharpoons Br^+ + AlCl_4^-$

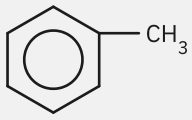


NOTE Three correct steps score 2 marks, and two correct steps score 1 mark. [2]

14 **(a)**

$C_6H_5CH_3 + 9O_2 \rightarrow 7CO_2 + 4H_2O$ [1]

(b)

$CH_3CH_2CH_2CH_2CH_2CH_2CH_3 \rightarrow$  $+ 4H_2$ [1]

(c)

High temperature. [1]

By Le Chatelier's Principle, the system would attempt to counter the high temperature by absorbing heat, hence favouring the forward reaction, which is endothermic. [1]

(d)

Since the forward reaction leads to the formation of more gaseous particles, a **low pressure** would favour a high equilibrium yield. [1]

By Le Chatelier's Principle, the system would attempt to counter the low pressure by producing more gaseous particles, hence favouring the forward reaction. [1]

(e)

$CH_3C_6H_4CH_3 + 6[O] \rightarrow HO_2CC_6H_4CO_2H + 2H_2O$ [1]