Exercise walk-through

Phenol ▪ 32.2

eXercise

You must be able to

- give the reactions of phenol (with bases, sodium, bromine water, dilute HNO_3)
- explain why phenol is more acidic than water or an alcohol
- explain why phenol reacts under milder conditions than benzene

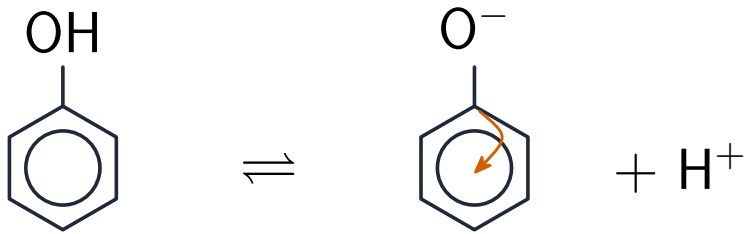
Method — Acidity and ring reactivity

- **acidity order:** ethanol $<$ water $<$ **phenol** ($<$ carboxylic acid).
- phenol's –OH loses H^+ $\rightarrow$ phenoxide; the charge is delocalised into the ring $\rightarrow$ stable ion $\rightarrow$ more acidic.

Phenol's ring is activated, so bromine water brominates positions 2, 4, 6 at room temperature, no catalyst — a white precipitate

- the O lone pair feeds into the ring $\rightarrow$ ring is electron-rich $\rightarrow$ reacts faster and milder than benzene.

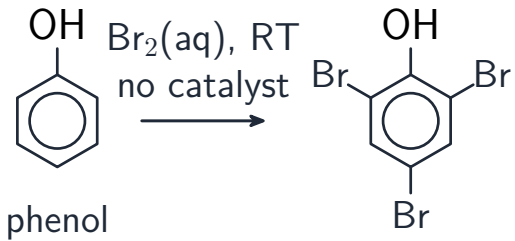
Method — Acidity and ring reactivity



phenol phenoxide (charge spread into ring)

acidity: ethanol < water < phenol

Method — Acidity and ring reactivity



phenol

2,4,6-tribromophenol
(white precipitate)

the ring is activated, so milder conditions than benzene

Phenol + bromine water at room temperature → 2,4,6-tribromophenol, a white precipitate

Practice 2.1 ▪ 1 mark

Name the organic product when phenol reacts with bromine water.

Solution 2.1

Method: Acidity and ring reactivity

Worked steps

2,4,6-tribromophenol B1.

Practice 2.2 ▪ 1 mark

State what you would see when phenol reacts with bromine water.

Solution 2.2

Method: Acidity and ring reactivity

Worked steps

a white precipitate forms / the bromine water decolourises B1.

Exam-style 3.1 ▪ 1 mark

Phenol is more acidic than ethanol because:

A the phenoxide ion's charge is delocalised into the ring

B phenol contains a benzene ring

C ethanol has no –OH group

D phenol is a strong acid

Solution 3.1

Method: Acidity and ring reactivity

A the phenoxide ion's charge is delocalised into the ring ✓

B phenol contains a benzene ring

C ethanol has no –OH group

D phenol is a strong acid

Worked steps

A. The negative charge on the phenoxide ion is delocalised into the ring, stabilising it.

Exam-style 3.2 ▪ 1 mark

Phenol reacts with bromine water **faster** than benzene reacts with bromine because in phenol:

A the ring is electron-poor

B an O lone pair feeds electron density into the ring

C the –OH removes electrons from the ring

D a catalyst is present

Solution 3.2

Method: Acidity and ring reactivity

A the ring is electron-poor

B an O lone pair feeds electron density into the ring ✓

C the –OH removes electrons from the ring

D a catalyst is present

Worked steps

B. An oxygen lone pair feeds into the ring, making it more electron-rich and reactive.

Exam-style 3.3 ▪ 2 marks

Phenol reacts with sodium hydroxide solution, but ethanol does not.
(a) Write the equation for phenol with NaOH(aq).
(b) State what this difference shows about phenol.

Solution 3.3

Method: Acidity and ring reactivity

Worked steps

(a) $C_6H_5OH + NaOH \rightarrow C_6H_5ONa + H_2O$ **M1** **A1** *sodium phenoxide, balanced.*
(b) phenol is acidic (more acidic than an alcohol — it reacts with a base) **B1**.

Exam-style 3.4 ▪ 3 marks

Explain why phenol can be brominated with bromine water at room temperature with no catalyst, while benzene needs a halogen carrier.

Solution 3.4

Method: Acidity and ring reactivity

Worked steps

a lone pair on the phenol oxygen is delocalised into the ring **M1**; this makes the ring more electron-rich, so it attracts electrophiles more strongly **M1**; benzene's ring is less electron-rich, so it needs a halogen carrier to make a strong enough electrophile **A1**.