

Exercise walk-through

32.2

Phenol

A-Level Chemistry

Alcohols with acyl chlorides



An alcohol reacts with an **acyl chloride** to make an **ester** – **faster & more completely** than with a carboxylic acid. Ethanol + ethanoyl chloride → ethyl ethanoate + HCl.

Phenol and its reactions



Phenol has —OH joined to a benzene ring:

- $+ \text{NaOH} \rightarrow$ sodium phenoxide (alcohols don't react!)
- $+ \text{Na} \rightarrow \text{H}_2$
- nitration (dilute) & **bromination** at room temp
- $+ \text{diazonium} \rightarrow$ a coloured **azo dye**

The reactions of phenol

with sodium

fizzes, giving sodium phenoxide and hydrogen – phenol is **acidic enough** for this

with NaOH(aq)

forms sodium phenoxide; but **not** with carbonate, since phenol is weaker than carbonic acid

with bromine water

decolourises it **immediately** and without a catalyst, giving 2,4,6-tribromophenol as a white precipitate

why so easy

a lone pair on the oxygen delocalises into the ring, **activating** it

with a diazonium salt

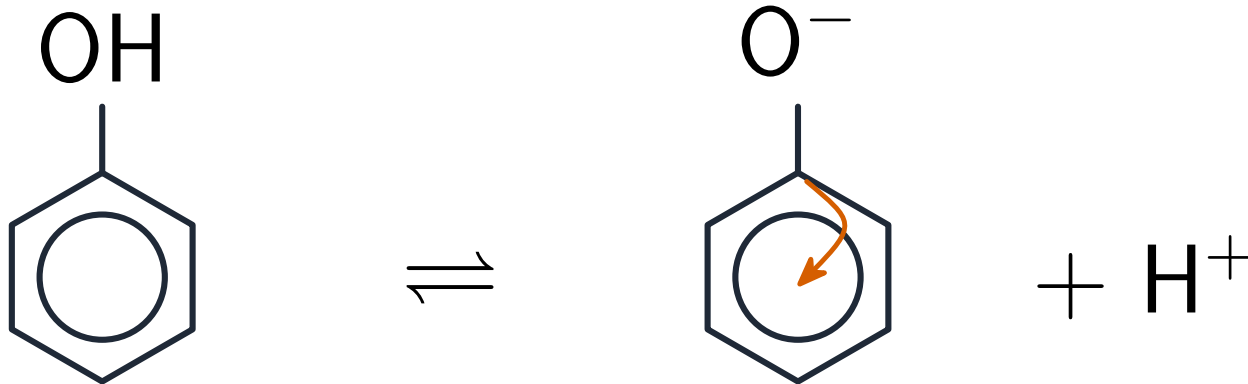
in NaOH(aq), forms a coloured **azo compound** –
the basis of many dyes

That last reaction is the whole azo-dye industry. The colour comes from the extended delocalisation across the —N=N— bridge.

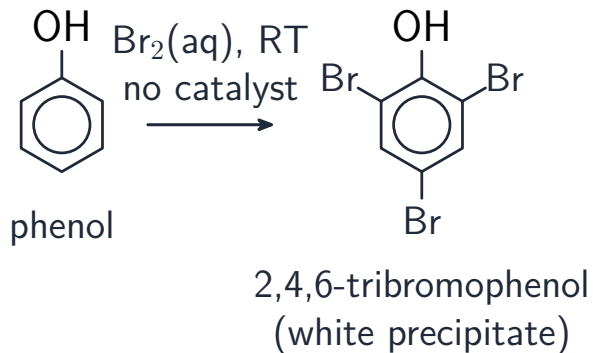
Acidity of phenol

Phenol loses H^+ to a **phenoxide** ion, stabilised by spreading the charge into the ring.

So acidity is: ethanol < water < phenol (but phenol is still weaker than a carboxylic acid).



Milder conditions than benzene



the ring is activated, so milder conditions than benzene

The O lone pair is **delocalised** into the ring, making it more electron-rich and **activated**.

So bromine water brominates phenol at the 2,4,6-positions at **room temperature, no catalyst** – a white precipitate.

Exercises 2.1·3.1

2.1 Name the organic product when phenol reacts with bromine water. [1]

2.2 State what you would see when phenol reacts with bromine water. [1]

3.1 Phenol is more acidic than ethanol because: [1]

- ☐ **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

Exercises 2.1·3.1

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- 2,4,6-tribromophenol

2.2 State what you would see when phenol reacts with bromine water. [1]

2.2

- a white precipitate forms / the bromine water decolourises

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☐

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

3.1 A

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

Exercise 3.2

3.2 Phenol reacts with bromine water **faster** than benzene reacts with bromine because in phenol: [1]

☐

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

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B an O lone pair feeds electron density into the ring

C the -OH removes electrons from the ring

D a catalyst is present

3.2 B

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

Exercise 3.3 (a)

3.3 Phenol reacts with sodium hydroxide solution, but ethanol does not.

(a) Write the equation for phenol with NaOH(aq).

[2]

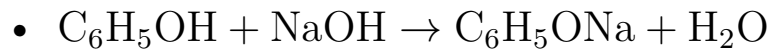
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Exercise 3.3 (b)

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(b) State what this difference shows about phenol.

[1]

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[1]

(b)

- phenol is acidic (more acidic than an alcohol – it reacts with a base)

Exercise 3.4

3.4 Explain why phenol can be brominated with bromine water at room temperature with no catalyst, while benzene needs a halogen carrier. [3]

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3.4

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

Exercise 3.5 (a)

3.5 Phenol, $\text{C}_6\text{H}_5\text{OH}$, is a weak acid; ethanol is not acidic in water.

(a) Write the equation for the reaction of phenol with aqueous sodium hydroxide, and name the salt formed. [2]

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- $\text{C}_6\text{H}_5\text{OH} + \text{NaOH} \rightarrow \text{C}_6\text{H}_5\text{O}^-\text{Na}^+ + \text{H}_2\text{O}$; the salt is **sodium phenoxide**

Exercise 3.5 (b)

3.5 Phenol, $\text{C}_6\text{H}_5\text{OH}$, is a weak acid; ethanol is not acidic in water.

(b) Explain, in terms of the stability of the anion, why phenol is a stronger acid than ethanol but weaker than ethanoic acid. [4]

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- In the phenoxide ion a lone pair on the oxygen is delocalised into the ring's π system, so the negative charge is spread out and the ion is stabilised – the equilibrium therefore lies further to the right than for ethanol, whose ethoxide has no such delocalisation. In ethanoate the charge is delocalised over **two electronegative oxygens** only, which stabilises it far more effectively than spreading it round a carbon ring, so ethanoic acid is the strongest of the three

Exercise 3.5 (c)

3.5 Phenol, $\text{C}_6\text{H}_5\text{OH}$, is a weak acid; ethanol is not acidic in water.

(c) Phenol reacts with bromine **water** at room temperature to give a white precipitate, whereas benzene needs a halogen carrier and heat. Write the equation for the phenol reaction and explain the difference in reactivity.

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- $\text{C}_6\text{H}_5\text{OH} + 3\text{Br}_2 \rightarrow \text{C}_6\text{H}_2\text{Br}_3\text{OH} + 3\text{HBr}$ – white 2,4,6-tribromophenol. The oxygen's lone pair is donated into the ring, raising its electron density so it polarises an approaching bromine molecule by itself – no halogen carrier is needed

Exercise 3.5 (d)

3.5 Phenol, $\text{C}_6\text{H}_5\text{OH}$, is a weak acid; ethanol is not acidic in water.

(d) State a chemical test that distinguishes phenol from ethanol, with the result for each. [2]

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(d)

- Add neutral iron(III) chloride solution: phenol gives a violet/purple colour, ethanol gives no change. (Sodium carbonate is **not** a valid test – neither gives carbon dioxide.)