Compounds like alcohols and phenol which contain an -OH group attached to a hydrocarbon are very weak acids. Alcohols are so weakly acidic that, for normal lab purposes, their acidity can be virtually ignored. However, phenol is sufficiently acidic for it to have recognizably acidic properties - even if it is still a very weak acid. A hydrogen ion can break away from the -OH group and transfer to a base.

Why is phenol acidic?

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\[
\text{Phenol} + \text{H}_2\text{O} \rightleftharpoons \text{phenoxide} + \text{H}_3\text{O}^+
\]

Phenol is a very weak acid and the position of equilibrium lies well to the left. Phenol can lose a hydrogen ion because the phenoxide ion formed is stabilised to some extent. The negative charge on the oxygen atom is delocalised around the ring. The more stable the ion is, the more likely it is to form. One of the lone pairs on the oxygen atom overlaps with the delocalised electrons on the benzene ring.

This overlap leads to a delocalization which extends from the ring out over the oxygen atom. As a result, the negative charge is no longer entirely localized on the oxygen, but is spread out around the whole ion.
Spreading the charge around makes the ion more stable than it would be if all the charge remained on the oxygen. However, oxygen is the most electronegative element in the ion and the delocalized electrons will be drawn towards it. That means that there will still be a lot of charge around the oxygen which will tend to attract the hydrogen ion back again. That is why phenol is only a very weak acid.

Why is phenol a much stronger acid than cyclohexanol? To answer this question we must evaluate the manner in which an oxygen substituent interacts with the benzene ring. As noted in our earlier treatment of electrophilic aromatic substitution reactions, an oxygen substituent enhances the reactivity of the ring and favors electrophile attack at ortho and para sites. It was proposed that resonance delocalization of an oxygen non-bonded electron pair into the pi-electron system of the aromatic ring was responsible for this substituent effect. A similar set of resonance structures for the phenolate anion conjugate base appears below the phenol structures.

The resonance stabilization in these two cases is very different. An important principle of resonance is that charge separation diminishes the importance of canonical contributors to the resonance hybrid and reduces the overall stabilization. The contributing structures to the phenol hybrid all suffer charge separation, resulting in very modest stabilization of this compound. On the other hand, the phenol anion is already charged, and the canonical contributors act to disperse the charge, resulting in a substantial stabilization of this species. The conjugate bases of simple alcohols are not stabilized by charge delocalization, so the acidity of these compounds is similar to that of water. An energy diagram showing the effect of resonance on cyclohexanol and phenol acidities is shown on the right. Since the resonance stabilization of the phenolate conjugate base is much greater than the stabilization of phenol itself, the acidity of phenol relative to cyclohexanol is increased. Supporting evidence that the phenolate negative charge is delocalized on the ortho and para carbons of the benzene ring comes from the influence of electron-withdrawing substituents at those sites.

Properties of phenol as an acid

With indicators

The pH of a typical dilute solution of phenol in water is likely to be around 5 - 6 (depending on its concentration). That means that a very dilute solution isn't really acidic enough to turn litmus paper fully red. Litmus paper is blue at pH 8 and red at pH 5. Anything in between is going to show as some shade of "neutral". Phenol reacts with sodium hydroxide solution to give a colourless solution containing sodium phenoxide.

\[
\text{OH} + \text{NaOH} \rightarrow \text{O}^{-} \text{Na}^{+} + \text{H}_{2}\text{C}
\]

sodium phenoxide

In this reaction, the hydrogen ion has been removed by the strongly basic hydroxide ion in the sodium hydroxide solution.

With sodium carbonate or sodium hydrogencarbonate

Phenol isn't acidic enough to react with either of these. Or, looked at another way, the carbonate and hydrogencarbonate
ions aren't strong enough bases to take a hydrogen ion from the phenol. Unlike the majority of acids, phenol does not give carbon dioxide when you mix it with one of these. This lack of reaction is actually useful. You can recognise phenol because:

- It is fairly insoluble in water.
- It reacts with sodium hydroxide solution to give a colourless solution (and therefore must be acidic).
- It does not react with sodium carbonate or hydrogencarbonate solutions (and so must be only very weakly acidic).

**With metallic sodium**

Acids react with the more reactive metals to give hydrogen gas. Phenol is no exception - the only difference is the slow reaction because phenol is such a weak acid. Phenol is warmed in a dry tube until it is molten, and a small piece of sodium added. There is some fizzing as hydrogen gas is given off. The mixture left in the tube will contain sodium phenoxide.

![Chemical reaction diagram]

**Contributors**

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