

- longer alcohols are generally not miscible with water.

e.g. CH₃CH₂CH₂CH₂OH soluble in H₂O, but not fully miscible in all amounts

- less dense than water $\rho < 1.0$

- good solvents for polar + non-polar compounds

 $R-O-H-\cdots O-R$ H-bonding results in high B.P and M.P.

 $\begin{array}{c} {\rm CH_{3}OH} & {\rm CH_{3}CH_{3}} \\ {\rm MW} & {\rm 32} & {\rm 30} \\ {\rm BP} & {\rm + 65^{\circ}C} & {\rm - 88^{\circ}C} \end{array}$

Properties of Ethers

- non-polar (relatively), generally unreactive, especially to base

- have dipole-dipole interactions,



ethyl ether



- H-bond acceptors but NOT H-bond donors,

- not miscible with water, good solvents for organic compounds.
- low B.P. and M.P. than alcohols but higher than hydrocarbons.

eg. $CH_3CH_2OCH_2CH_3$ BP = 35 °C

Acidity of Alcohols:

Let's review some basic definitions

 $\operatorname{HA} \underbrace{\longleftrightarrow}_{HA} \stackrel{\forall}{\longleftarrow} H \qquad : A^{\bigcirc}$ (+)

HA is the conjugate acid of A⁻, and A⁻ is the conjugate base of HA.

The equilibrium constant, or acidity constant, K_a , for this reaction can be expressed as: $K_a = [\mathrm{H}^+] [\mathrm{A}^-] / [\mathrm{HA}]$

For example: the dissociation of methanol

 $K_a = [H^+][CH_3O^-] / [CH_3OH] = 10^{-16}$

The oxygen of the OH group in methanol has a partial negative charge and the hydrogen has a partial positive charge. The O-H bond is easy to break and it can break spontaneously. When methanol with OH is put in a solution of methanol with O-D (deuterium), the hydrogen will exchange rapidly against deuterium.

By analogy with pH, we can define a quantity pK_a , which is often used. $pK_a = -\log K_a$

Generally, the stronger the acid, the lower the pK_a .

The p K_a value for methanol is 16, for water is 15.7 (know these values). Since the p K_a value of water is less than methanol, the dissociation of methanol is harder than water and water is a stronger acid than methanol.

Remember that the pK_a and pK_w for water are not the same. $K_w = [H^+][OH^-],$ $K_a = [H^+][OH^-]/(H_2O]$

Examples:

The p K_a value of methane is about 45. It is not acidic.

What happens when we replace the carbon with nitrogen, a heteroatom?

$$H-N-H \longrightarrow H-N \oplus H$$

The p K_a value of ammonia is 36, which is 9 orders of magnitude (10⁹) more acidic than methane. This is because the nitrogen atom is more electronegative than carbon and able to stabilize the negative charge better. However, ammonia is still a very weak acid. The acidity of ammonia (NH₃) should not be confused with the acidity of the ammonium ion (NH₄⁺) which has a pK_a of 9.26.

Based on pK_a values, is oxygen more or less electron withdrawing than nitrogen? Answer: Oxygen is more electron withdrawing. It has lower pKa value, able to stabilize the negative charge more.

Name	Structure	рКа	Less acidic
methane	CH ₄	46	
ammonia	NH ₃	36	
water	НОН	15.7	
hydrofluoric acid	HF	3.2	More acidic

Recall from last term, **the stability of the conjugate anion determines the acidity of a compound**. The more stabilized the anion is, more acidic the molecule is.

Name	Structure	рКа	
methanol	H ₃ C-OH	16	
ethanol	CH ₃ -CH ₂ -OH	17	
isopropyl alcohol		18	
tert-butanol		19	

What do these pK_a values mean in reactions?

$$\overset{CH_{3}}{\underset{CH_{3}}{\overset{H-C-OH}{\longleftarrow}}} \overset{CH_{3}}{\underset{CH_{3}}{\overset{H-C-O}{\longleftarrow}}} \overset{CH_{3}}{\underset{CH_{3}}{\overset{H-C-O}{\longleftarrow}}} + \overset{(\oplus)}{\underset{CH_{3}}{\overset{(\oplus)}{\overset{H-C-O}{\longleftarrow}}}} + \overset{(\oplus)}{\underset{CH_{3}}{\overset{(\oplus)}{\overset{H-C-O}{\overset{H-C-O}{\longleftarrow}}}} + \overset{(\oplus)}{\underset{CH_{3}}{\overset{(\oplus)}{\overset{H-C-O}{\overset{H-C-$$

Isopropanol dissociates to from isopropoxide anion and a proton. However, the dissociation constant is 1×10^{-18} . Most of the molecules exist in the isopropanol form and only one part in 10^{18} is ionized. The equilibrium for this reaction lies far to the left.

There are two alkyl groups attached to the central carbon bearing oxygen in isopropanol. The alkyl groups (methyls) donate electron density to that carbon (an inductive effect) that is already next to a negative charged center (O^{-}). Since negative charges repel each other, the anion is less stabilized. Therefore, the anion is even less likely to form (less stabilized than if the alkyl groups (methyls) in isopropanol were missing.

Methanol (pK_a 16) is 100 times (10^2) more acidic than isopropanol, since it has only hydrogens (a less donating group) attached to the carbon bearing the negative oxygen in the corresponding anion)

$$H \xrightarrow{I}_{-C} -OH \xrightarrow{H}_{-C} H \xrightarrow{H}_{-C} O^{\bigcirc} + H^{\oplus}$$

For *tert*-butanol (tert-butyl alcohol), there are three alkyl groups (methyls) that donate electron density to the carbon next to a negative charged group (inductive donation of electrons destabilizes the anion). Therefore, it is less likely to dissociate (pK_a 19) and the molecule is even less likely to ionize (less acidic).

$$\begin{array}{c} \mathsf{CH}_{3} \\ \mathsf{H}_{3}\mathsf{C}-\overset{\mathsf{CH}_{3}}{\mathsf{C}-\mathsf{O}}-\mathsf{OH} \xrightarrow{\mathsf{CH}_{3}} \\ \mathsf{H}_{3}\mathsf{C}-\overset{\mathsf{CH}_{3}}{\mathsf{C}-\mathsf{O}} \\ \mathsf{CH}_{3} \end{array} \overset{\mathsf{CH}_{3}}{\mathsf{CH}_{3}} + \overset{\mathsf{H}^{\oplus}}{\mathsf{CH}_{3}} \end{array}$$

Consider the example below:



Where does the equilibrium lie in the above reaction? Answer: It lies far to the right.

The reaction of a stronger base (tert-butoxide) and a stronger acid (water) to a weaker base (potassium hydroxide) and weaker acid (tert-butanol) is very fast.



Inductive & Resonance

As the pK_a values above show, phenol is 10^8 more acidic than cyclohexanol.

Phenol has a pK_a value of 10 (given this information, you should immediately recognize that it is more much acidic (about 6 orders of magnitude) than water (pK_a 15.7) and methanol (pK_a 16) since it has lower pK_a value). As phenol is more acidic, this means that its conjugate anion is more stable. The phenoxide anion is stabilized through resonance (shown above). It has 4 resonance forms, and therefore, more ability to spread the negative charge and be stabilized.