Leveling effect

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Acid-base discrimination windows of common solvents[1]

**Leveling effect** or **solvent leveling** refers to the effect of **solvent** on the properties of acids and bases. The strength of a **strong acid** is limited ("leveled") by the basicity of the solvent. Similarly the strength of a **strong base** is leveled by the acidity of the solvent. When a strong acid is dissolved in water, it reacts with it to form **hydronium ion** (H$_3$O$^+$).[2] An example of this would be the following reaction, where "HA" is the strong acid:

$$\text{HA} + \text{H}_2\text{O} \rightarrow \text{A}^- + \text{H}_3\text{O}^+$$

Any acid that is stronger than H$_3$O$^+$ reacts with H$_2$O to form H$_3$O$^+$. Therefore, no acid stronger than H$_3$O$^+$ exists in H$_2$O. Similarly, when **ammonia** is the solvent, the strongest acid is **ammonium** (NH$_4^+$), thus HCl and a **super acid** exert the same acidifying effect.

The same argument applies to bases. In water, OH$^-$ is the strongest base. Thus, even though **sodium amide** (NaNH$_2$) is an exceptional base (pK$_a$ of NH$_3$ ~ 33), in water it is only as good as sodium hydroxide. On the other hand, NaNH$_2$ is a far more basic reagent in ammonia than is NaOH.

The pH range allowed by a particular solvent is called the acid-base discrimination window.[1]

**Leveling and differentiating solvents**

In a **differentiating solvent**, various acids dissociate to different degrees and thus have different strengths. In a **leveling solvent**, several acids are completely dissociated and are thus of the same strength. A weakly basic solvent has less tendency than a strongly basic one to accept a **proton**. Similarly a weak acid has less tendency to donate protons than a strong acid. As a result a strong acid such as **perchloric acid** exhibits more strongly acidic properties than a weak acid such as **acetic acid** when dissolved in a weakly basic solvent. On the other hand, all acids tend to become indistinguishable in strength when dissolved in strongly basic solvents owing to the greater affinity of strong bases for protons. This is called the leveling effect. Strong bases are **leveling solvents** for acids, weak bases are **differentiating solvents** for acids. Because of the leveling effect of common solvents, studies on super acids are conducted in solvents that are very weakly basic such as **sulfur dioxide** (liquefied) and SO$_2$ClF.[3]
Types of solvent on the basis of proton interaction On the basis of proton interaction, solvents are of four types,

(i) Protophilic solvents: Solvents which have greater tendency to accept protons, i.e., water, alcohol, liquid ammonia, etc.

(ii) Protogenic solvents: Solvents which have the tendency to produce protons, i.e., water, liquid hydrogen chloride, glacial acetic acid, etc.

(iii) Amphiprotic solvents: Solvents which act both as protophilic or protogenic, e.g., water, ammonia, ethyl alcohol, etc.

(iv) Aprotic solvents: Solvents which neither donate nor accept protons, e.g., benzene, carbon tetrachloride, carbon disulphide, etc.

HCl acts as an acid in H₂O, a stronger acid in NH₃, a weak acid in CH₃COOH, neutral in C₆H₆ and a weak base in HF.

References