Fenton's reagent

Fenton's reagent is a solution of hydrogen peroxide (H_2O_2) with ferrous iron (typically iron(II) sulfate, $FeSO_4$) as a catalyst that is used to oxidize contaminants or waste waters. Fenton's reagent can be used to destroy organic compounds such as trichloroethylene (TCE) and tetrachloroethylene (perchloroethylene, PCE). It was developed in the 1890s by Henry John Horstman Fenton as an analytical reagent.[1][2][3]

Contents

Overview

Iron(II) is oxidized by hydrogen peroxide to iron(III), forming a hydroxyl radical and a hydroxide ion in the process. Iron(III) is then reduced back to iron(II) by another molecule of hydrogen peroxide, forming a hydroperoxyl radical and a proton. The net effect is a disproportionation of hydrogen peroxide to create two different oxygen-radical species, with water ($H^+ + OH^-$) as a byproduct.

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + HO\bullet + OH^- \quad \textbf{(1)}$$

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + HOO\bullet + H^+ \quad \textbf{(2)}$$

$$2\ H_2O_2 \rightarrow HO\bullet + HOO\bullet + H_2O \quad \textbf{(net reaction: 1+2)}$$

The free radicals generated by this process then engage in secondary reactions. For example, the hydroxyl is a powerful, non-selective oxidant. Oxidation of an organic compound by Fenton's reagent is rapid and exothermic and results in the oxidation of contaminants to primarily carbon dioxide and water.[4]

Reaction (**1**) was suggested by Haber and Weiss in the 1930s as part of what would become the Haber–Weiss reaction.[5]

Iron(II) sulfate is typically used as the iron catalyst. The exact mechanisms of the redox cycle are uncertain, and non-OH• oxidizing mechanisms of organic compounds have also been suggested. Therefore, it may be appropriate to broadly discuss *Fenton chemistry* rather than a specific *Fenton reaction*.

In the electro-Fenton process, hydrogen peroxide is produced *in situ* from the electrochemical reduction of oxygen.[6]

Fenton's reagent is also used in organic synthesis for the hydroxylation of arenes in a radical substitution reaction such as the classical conversion of benzene into phenol.

$$C_6H_6 + FeSO_4 + H_2O_2 \rightarrow C_6H_5OH \quad \textbf{(3)}$$

An example hydroxylation reaction involves the oxidation of barbituric acid to alloxane.[7] Another application of the reagent in organic synthesis is in coupling reactions of alkanes. As an example *tert*-butanol is dimerized with Fenton's reagent and sulfuric acid to 2,5-dimethyl-2,5-hexanediol.[8]

Effect of pH on the reaction rate

As the Fenton reaction depends on the simultaneous presence (in solution) of dissolved Fe^{2+} and Fe^{3+} ions, its kinetics are influenced by the respective solubilities of both species as a direct-function of the solution's pH. As Fe^{3+} is about 100 times less soluble than Fe^{2+} in natural water at near-neutral pH, the ferric ion concentration is the limiting factor for the reaction rate. The reaction only proceeds rapidly under acidic conditions. At high pH, under alkaline conditions, the reaction slows down due to precipitation of $Fe(OH)_3$, lowering the concentration of the Fe^{3+} species in solution.

Biomedical implications

The Fenton reaction has different implications in biology because it involves the formation of free radicals by chemical species naturally present in the cell under *in vivo* conditions.[9] Transition-metal ions such as iron and copper can donate or accept free electrons via intracellular reactions and so contribute to the formation, or at the contrary to the scavenging, of free radicals. In oxygen respirating organisms, most of the intracellular iron is in

the ferric (Fe^{3+}) state and must therefore be reduced to the ferrous (Fe^{2+}) form to take part in the Fenton reaction. Superoxide ions and transition metals act in a synergistic way in the appearance of free radical damages.[10] Therefore, although the clinical significance is still unclear, it is one of the viable reasons to avoid iron supplementation in patients with active infections, whereas other reasons include iron-mediated infections.[11]

See also

- Carbon monoxide-releasing molecules

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Further reading

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External links

- Reference Library Peroxide Applications (http://www.h2o2.com/applications/industrialwastewater/fentonsreagent.html)
- Companies that use Fenton's Reagent for chemical remediation: ORIN (http://www.orinrt.com)