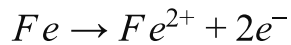


Steel corrosion is a multifaceted process that can take various forms depending on environmental conditions, the presence of chemicals or microorganisms, and the physical characteristics of the steel itself. Here, we'll dive into three distinct types of corrosion that steel can undergo: electrochemical corrosion, pitting corrosion, and microbial-induced corrosion, each with its own chemical mechanisms.

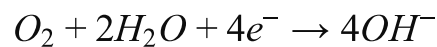
1. Electrochemical Corrosion

Electrochemical corrosion is the most common form of corrosion and occurs when metal in an electrolytic solution (such as water containing dissolved oxygen or salts) undergoes an oxidation-reduction (redox) reaction. This process involves two half-reactions: oxidation at the anode and reduction at the cathode.

- **Anodic Reaction (Oxidation):** At the anode, steel loses electrons, converting solid iron (Fe) into dissolved iron ions (Fe^{2+}):



- **Cathodic Reaction (Reduction):** At the cathode, typically, oxygen in water uses the electrons provided by the anode to form hydroxide ions (OH^{-}):

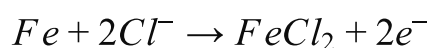


These reactions lead to the formation of rust ($Fe_2O_3 \cdot nH_2O$) when iron ions react with oxygen and water.

2. Pitting Corrosion

Pitting corrosion is a localized form of corrosion that leads to the creation of small, but deep, holes or pits in the metal. This type often occurs in the presence of chloride ions (Cl^{-}), such as those found in seawater or de-icing salts.

- **Initiation:** Pitting usually begins at defects on the metal surface, such as scratches or inclusions. The presence of Cl^{-} ions destabilizes the passive oxide layer on steel, leading to localized anodic areas.
- **Propagation:** Within these localized areas, Cl^{-} ions concentrate and contribute to the formation of a highly acidic environment. The acidic conditions accelerate the dissolution of metal, further deepening the pit.

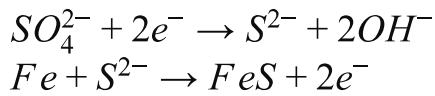


The localized nature of pitting corrosion can make it particularly dangerous, as it may lead to failure with minimal overall material loss.

3. Microbial Induced Corrosion (MIC)

Microbial induced corrosion involves the acceleration of corrosion processes due to the presence and activities of microorganisms, including bacteria and fungi. These microorganisms can influence corrosion in several ways:

- **Sulfate-Reducing Bacteria (SRB):** SRBs are among the most common culprits in MIC. They reduce sulfate (SO_4^{2-}) present in water or soil to sulfide (S^{2-}), which then reacts with iron to form iron sulfide (FeS), a corrosive layer on the steel surface.



- **Iron-Oxidizing Bacteria:** These bacteria directly oxidize iron to obtain energy, forming rust as a byproduct of their metabolism.
- **Acid-Producing Bacteria:** Some bacteria produce acidic byproducts from their metabolic activities, which can lower the pH and accelerate the corrosion process by enhancing metal dissolution.

MIC is especially challenging to manage due to the complexity of biological systems and their interactions with the abiotic environment. It often requires specific strategies, such as biocides, material selection, and control of environmental conditions, to mitigate.

In Summary

Each type of corrosion has its distinct chemical mechanisms, but all lead to the degradation of steel. Understanding these processes is essential for developing effective strategies to protect steel structures and components from corrosion, whether through material selection, protective coatings, environmental control, or the use of inhibitors and biocides.