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QUESTIONS

1. What is Corrosion?
2. With the aid of chemical reactions, briefly describe corrosion mechanisms
3. Give three (3) catastrophic incidences that had been recorded historically as a result of corrosion failure.

QUESTION 1

Corrosion is the deterioration or destruction of metals and alloys in the presence of an environment by chemical or electrochemical means. It involves reaction of metals with environmental species.

Corrosion is an irreversible interfacial reaction of a material (metal, ceramic, and polymer) with its environment which results in its consumption or dissolution into the material of a component of the environment. Often, but not necessarily, corrosion results in effects detriments to the usage of the material considered.

Also, corrosion by its simplest definition is the process of a metal returning to the material's thermodynamic state. For most materials, this means the formation of the oxides or sulphides from which they originally started when they were taken from the earth before being refined into useful engineering materials (Schweitzer, 2010).

QUESTION 2

Most commonly used metals are unstable in the atmosphere. These unstable metals are produced by reducing ores artificially, and therefore they tend to return to their original state or to similar metallic compounds when exposed to the atmosphere. Exceptions to this are gold and platinum, which are already in their metal state.

These changes are electrochemical reactions that follow the laws of thermodynamics. Understanding the interactions of materials with their environment now takes on the added dimension of chemistry and electricity. These concepts help explain why corrosion processes are time and temperature dependent. They also establish that the corrosion reactions, or rates, are affected by ion and corrodent concentrations, and explain why some reactions are reversible or controllable while others are not.

Corrosion in aqueous solutions is the most common of all corrosion processes. Water, seawater, and various process streams in industry provide an aqueous medium. Moisture in the atmosphere and water in the soil account for the aqueous corrosion in these media. In all these cases, water is seldom present in pure form. Rather, various salts and gases remain dissolved in it, and their dissociation renders the water somewhat conducting. For all practical purposes, it acts as an electrolyte. The chemical nature of this electrolyte may be acidic, alkaline, or neutral.

One of the most basic corrosion reactions involves the oxidation of a pure metal when exposed to a strong acid. A familiar case is that of pure iron coming in contact with hydrochloric acid. The resulting chemical reaction is obvious, with the solution beginning to bubble violently. The reaction can be expressed as follows:

$$Fe+2HCl \rightarrow FeCl_2 + H_2\uparrow \qquad (2.1)$$

We can see the result of this reaction by the gradual disappearance of the iron and the hydrogen bubbles rising rapidly to the surface. On an electrochemical level, there is also an exchange of electrons taking place:

$$Fe + 2H + Cl^{+2-} \rightarrow Fe^{2+} + Cl^{2-} + H_2\uparrow \qquad (2.2)$$

The iron has been converted to an iron ion by giving up two electrons (oxidation), which were picked up by the hydrogen ions. By gaining electrons, the hydrogen ion was reduced and formed hydrogen gas. Note that the chlorine atom does not enter into the reaction itself. The transfer of electrons is taking place on the surface of the metal. Those locations where electrons are being given up are identified as anodes. The sites where electrons are being absorbed are denoted as cathodes. A difference in electrical potential exists between these two areas and a complete electrical circuit develops. Negatively charged electrons flow in the direction of anode to cathode, and positively charged hydrogen ions in the solution move toward the cathode to complete the circuit. The faster the dissolution of the metal (rate of corrosion), the higher the current flow. The sites of the anodes and cathodes can change locations on the surface. In fact, this is exactly what happens when general or uniform corrosion takes place, with the anodic areas moving uniformly over the metal's surface (Schweitzer, 2010).

Anodic reactions in metallic corrosion are relatively simple. The reactions are always such that the metal is oxidized to a higher valence state. During general corrosion, this will result in the formation of metallic ions of all the alloying elements. Metals that are capable of exhibiting multiple valence states may go through several stages of oxidation during the corrosion process.

It should be noted that although the actual dissolution process of the metal is taking place through anodic reaction, cathodic reaction is equally important in the overall operation. The electrons liberated by anodic reaction are consumed in the cathodic process. A corroding metal does not accumulate any charge. It therefore follows that these two partial reactions of oxidation and reduction must proceed simultaneously and at the same rate to maintain this electro neutrality. Some basic concepts of corrosion control also evolve from this simple electrochemical picture. Retarding the cathodic process can retard metal dissolution; metal dissolution can also be retarded or stopped altogether by the supply of electrons to the corroding metal from any external source. The latter forms the basis of cathodic protection.

Cathodic reactions are more difficult to predict but can be categorized into one of five different types of reduction reactions:

Hydrogen evolution	Oxygen reduction in acids
$2H^+ + 2e^- \rightarrow H_2\uparrow$	$O_2 + 4H^+ + 2e^- \rightarrow 2H_2O$
Metal ion reduction	Metal deposition
M3+ + e− → M2+	$M^{2+} + 2e^- \rightarrow M$

Oxygen reduction-neutral solutions

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

QUESTION 3

Failures occur when a component or a structure is no longer able to withstand stresses imposed during exploitation. Usually, failures are related to stress concentration and they can occur for many reasons, including structural faults such as holes, notches and transitional curvatures of small diameters, cavities in the microstructure of materials as well as corrosive attacks, such as pitting, which generate local stress concentrations. The following are some of the catastrophic incidences that had been recorded historically as a result of corrosion failure.

1. **Damage of a turbine engine (England) 06/24/2013:** During Airbus A330 running at the airport in Manchester, at a speed of 190km/h, the right engine caught fire. The investigation showed that there had been a fracture of one of the turbine blades. The blade failed due to high cyclic fatigue initiated by corrosion pitting.
2. **Oil spills (Santa Barbara/California) 05/19/2015:** On one of the most biologically diverse coastlines in the United States, there was a discharge of 540m^3 of crude oil. Investigations indicated the presence of serious corrosion. In the lower quadrant of the pipeline, the thickness of which was reduced by 45% due to corrosion, there was crack propagation.
3. **The fall of railway traffic lights (Newbury/England) 11/17/2014:** A train travelling at 180km/h crashed into a railway traffic light that fell over two tracks. Corrosion caused almost a complete loss of the well of the hollow pylon.
4. **Landing of a Jetstream away from the runway (England) 08/15/2014:** Immediately after landing, the left leg of the landing gear separated from the shackles. The aircraft slid off the runway into the grass. The results of the investigation showed that the failure had been caused by stress corrosion (Petrovi, 2016).

REFERENCES

Petrovi, Z. C. (2016) 'CATASTROPHES CAUSED BY CORROSION', pp. 1048–1064. doi: 10.5937/vojtehg64-10388.

Schweitzer, P. A. (2010) *Fundamentals of Corrosion Mechanisms, Causes and Preventative Methods*.